Prompt fission neutron spectra of ^{235}U(n, F) and ^{239}Pu(n, F)

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Prompt fission neutron spectra of $^{235}U(n, F)$ and $^{239}Pu(n, F)$

Pre-fission $(n, 2nf)^{1,2}$ neutrons in $^{235}U(n,F)$ and $^{239}Pu(n,F)$

Anisotropy in pre-fission and $(n,n'\gamma)$ neutron spectra of $^{238}U+n$

Collaboration

“^{239}Pu(n, F) & “^{235}U(n,F) PROMPT FISSION NEUTRON SPECTRA”

WAS STARTED BY COLLABORATION OF 2008-2011

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4) EU-JRC Institute for Reference Materials and Measurements, Geel, Belgium

PFNS in Major Data Libraries (MDL)

1. PFNS discrepancies in MDL are often erroneously quoted as PFNS “uncertainty”

2. $^{235}U(n_{th}, f)$, $^{239}Pu(n_{th}, f)$ PFNS in MDL untill recently essentially mocked up each other

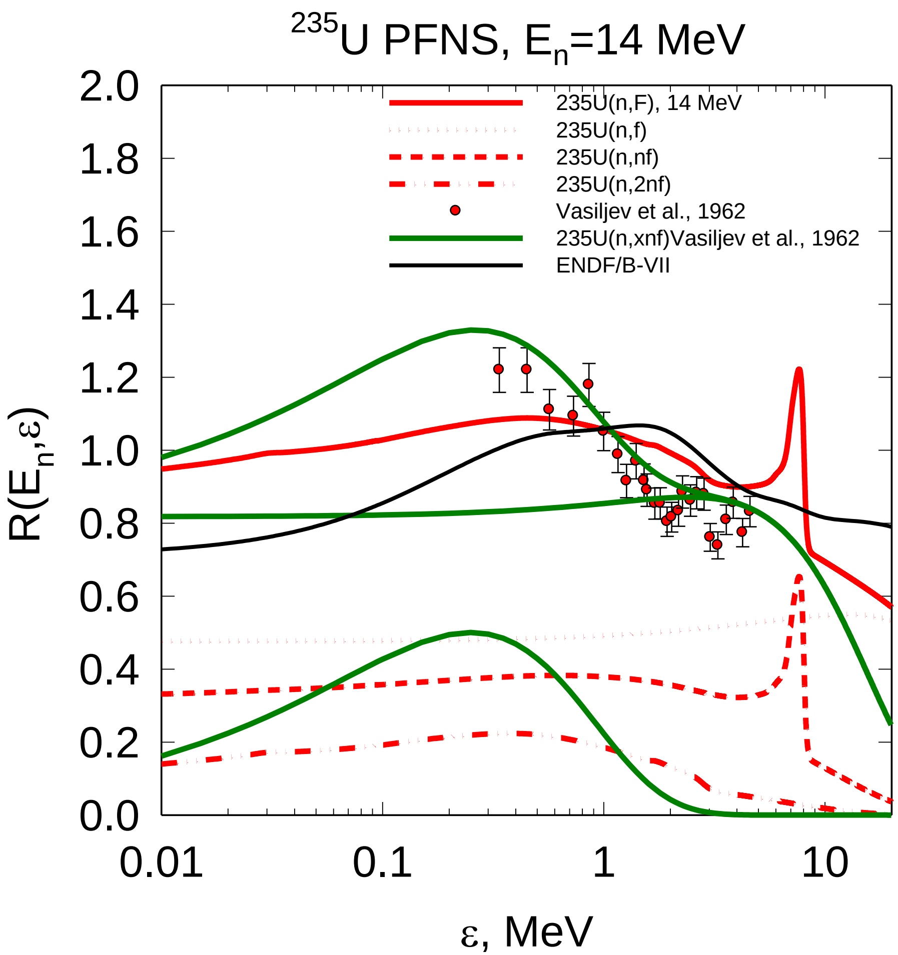
3. $^{235}U(n_{th}, f)$, $^{239}Pu(n_{th}, f)$ MDL’ PFNS are still discrepant with measured PFNS being well outside the biases of different data sets

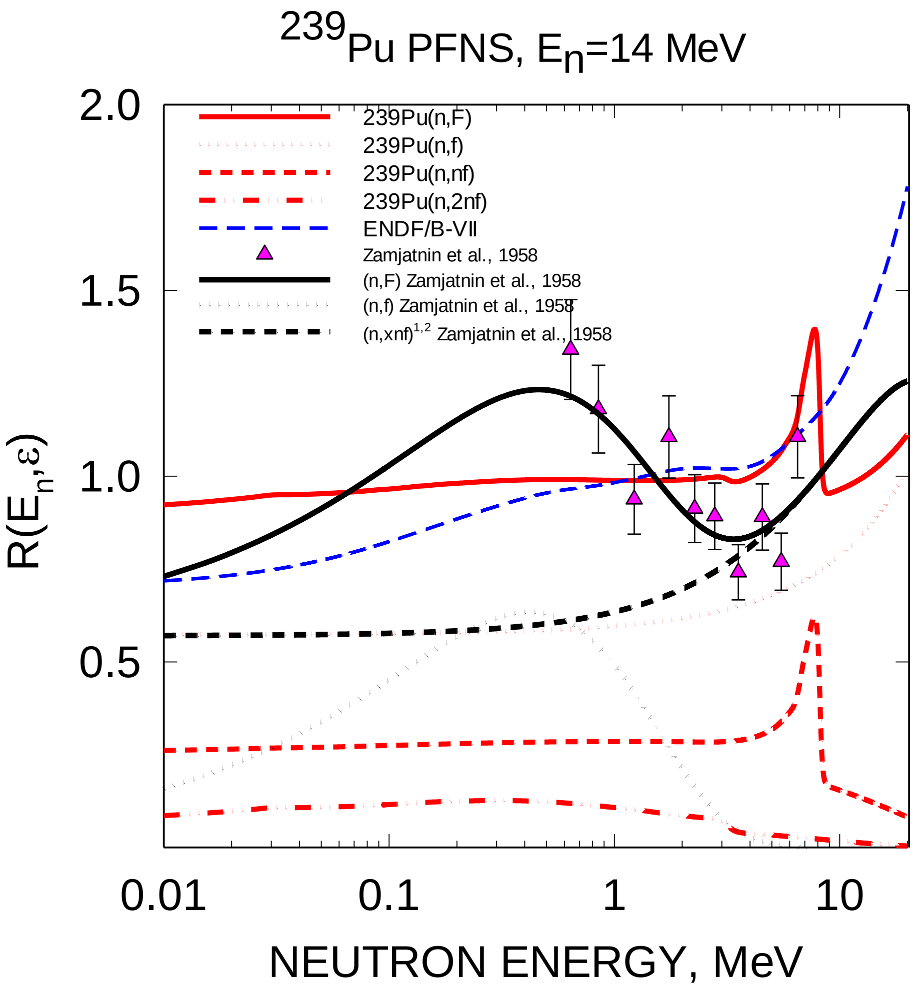
4. That may and still leads to arbitrary tweaking of neutron cross sections, neutron multiplicities to compensate ill-defined shapes of PFNS.

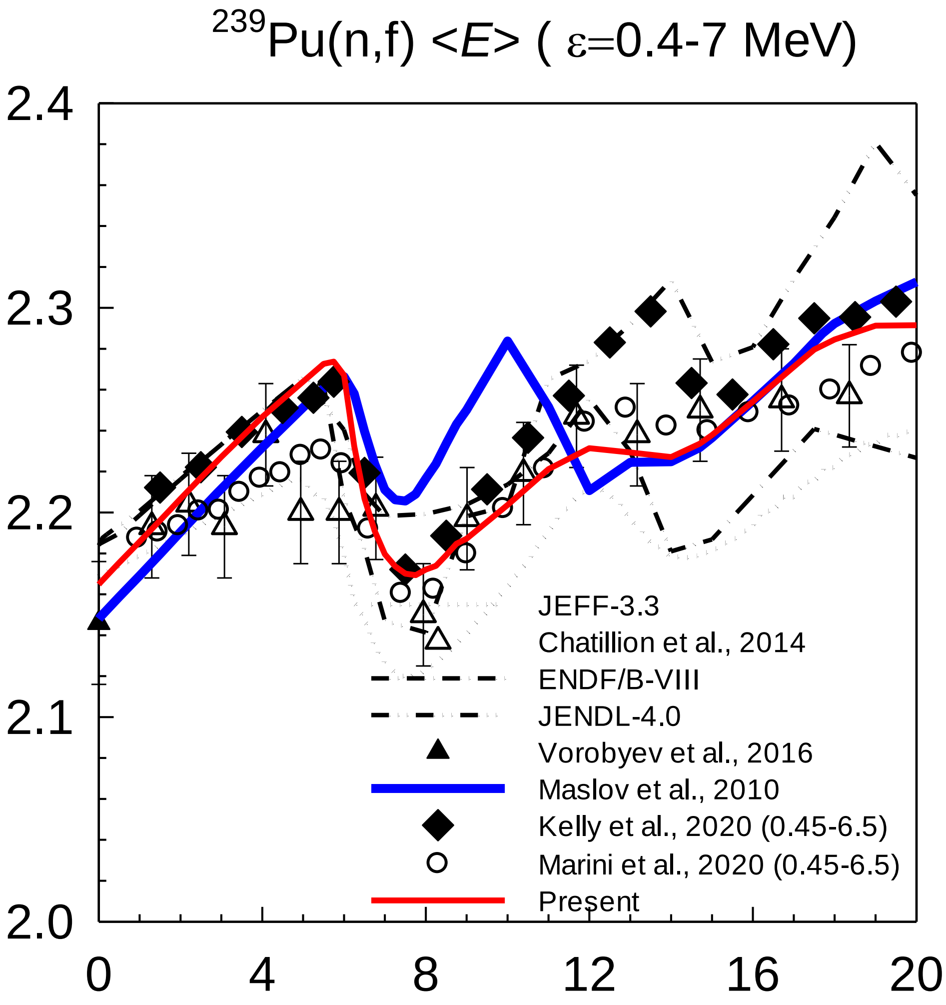
In Major Data Libraries PFNS at thermal E_n suffer from

1. Deficiency of soft neutrons,
2. Excess of neutrons with ε=1~3 MeV
3. Excess of hard-tail neutrons

$$S_{240}(\varepsilon, E_n) = (1-\beta)\varepsilon \exp\left(-\frac{\varepsilon}{T}\right) + \beta \exp\left(-\frac{\varepsilon}{T_f}\right)\frac{sh(2\sqrt{\omega\varepsilon})}{T_f}$$

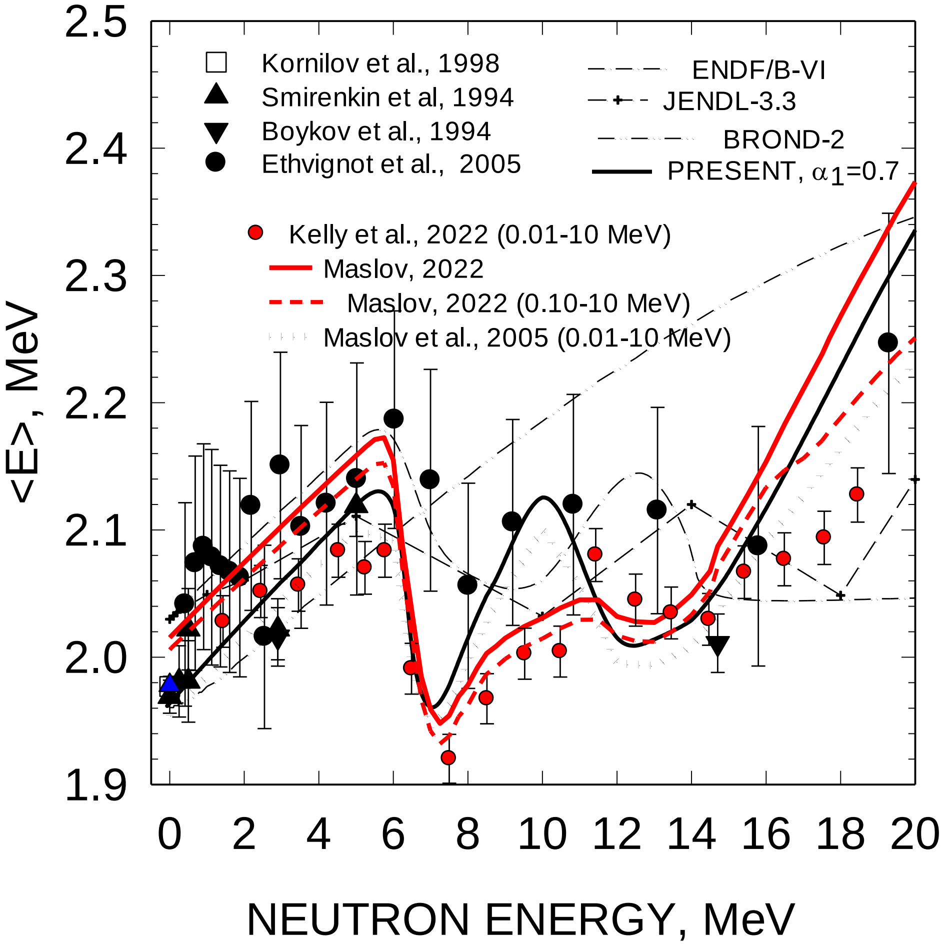




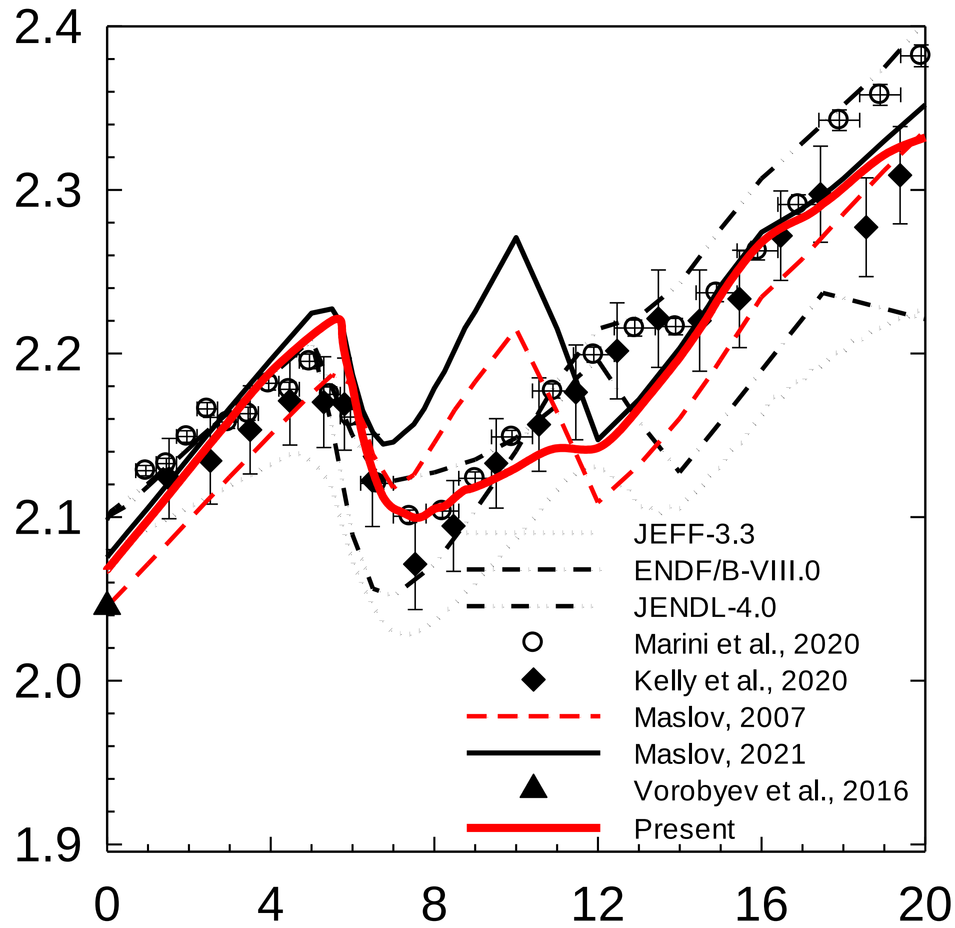


^{239}Pu(n,f) <E> (ε=0.4-7 MeV)
2.4
2.3
2.2
2.1
2.0
0
4
8
12
16
20
JEFF-3.3
Chatillion et al., 2014
ENDF/B-VIII
JENDL-4.0
Vorobyev et al., 2016
Maslov et al., 2010
Kelly et al., 2020 (0.45-6.5)
Marini et al., 2020 (0.45-6.5)
Present

^{235}U: AVERAGE ENERGY OF PFNS



^{239}Pu(n,F) <*E*> (ε=0.01-10 MeV)



Prompt fission neutron spectra

$S(\varepsilon,E_n)$ - sum of two Watt distributions:

-

$$S(\varepsilon,\mathrm{E_n}) = 0.5\sum_{i=1}^{2} W_i(\varepsilon, E_n, T_{ij}(E_n), \alpha)$$

Kornilov, Kagalenko, Hambsch, YaF, 62, 209, 1999

pre-acceleration NE + NE from accelerated fragments

$$W_i(\varepsilon, E_n, T_{ij}(E_n), \alpha) = \frac{2}{\sqrt{\pi} T_{ij}^{3/2}} \sqrt{\varepsilon} \exp(-\frac{E^*_{vij}}{T_{ij}}) \frac{sh(\sqrt{b_{ij}\varepsilon})}{\sqrt{b_{ij}\varepsilon}}$$

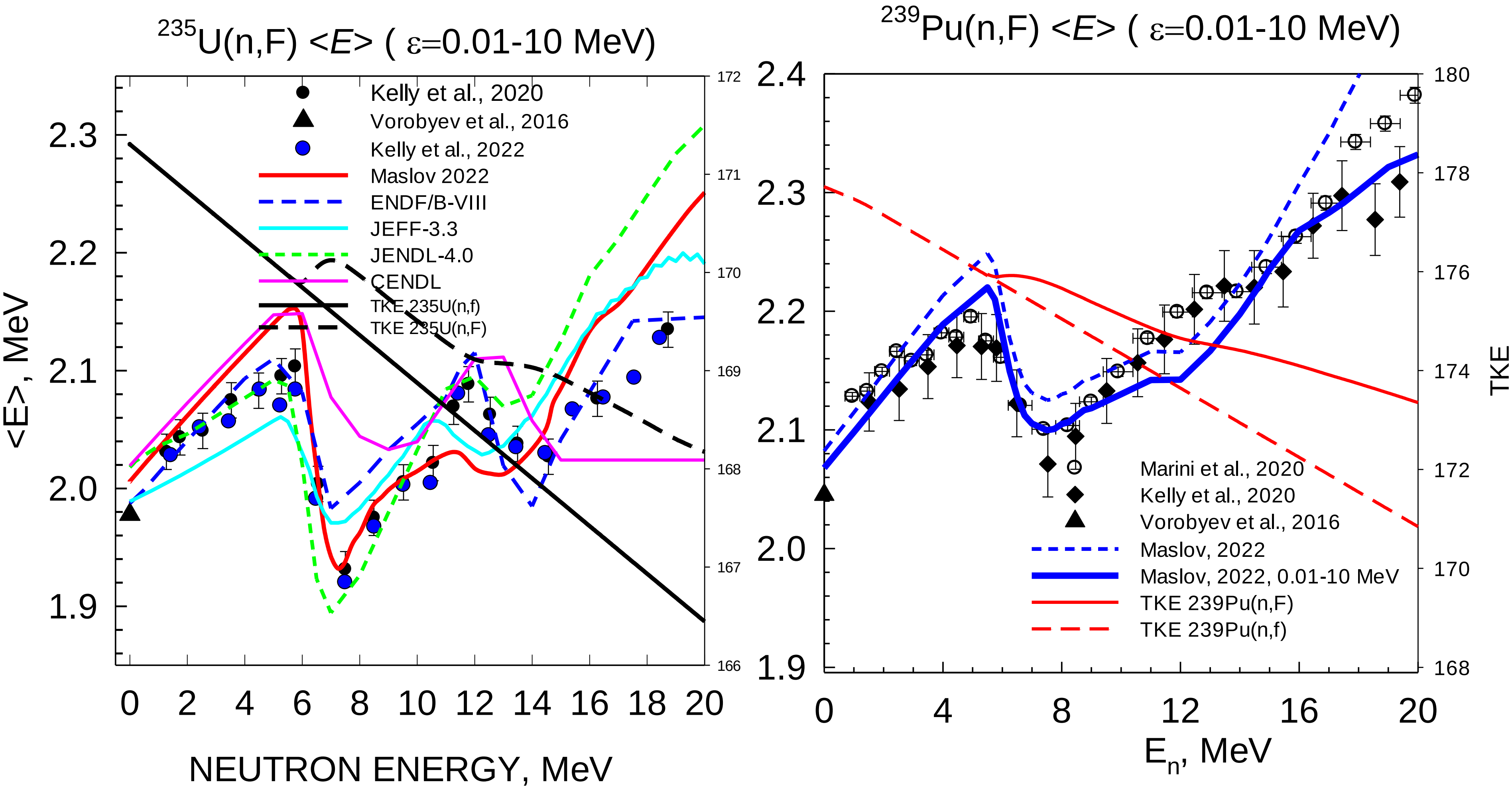
-

$$b_{ij} = \frac{4E^*_{vij}}{T_{ij}}, T_{ij} = k_{ij}\sqrt{E_r - TKE_i - U_i}$$

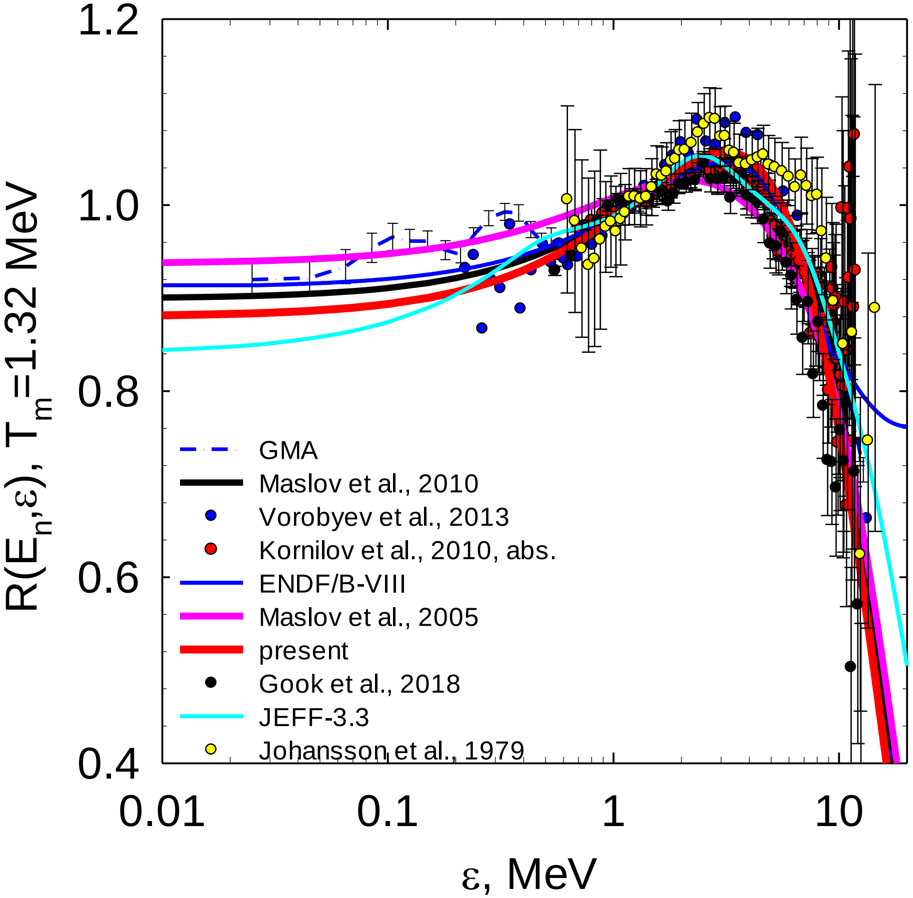
T_{ij} **-temperature for light and heavy fragments, α =TKE/TKE$_{\infty}$**

In Watt' equation CMS energy per nucleon -

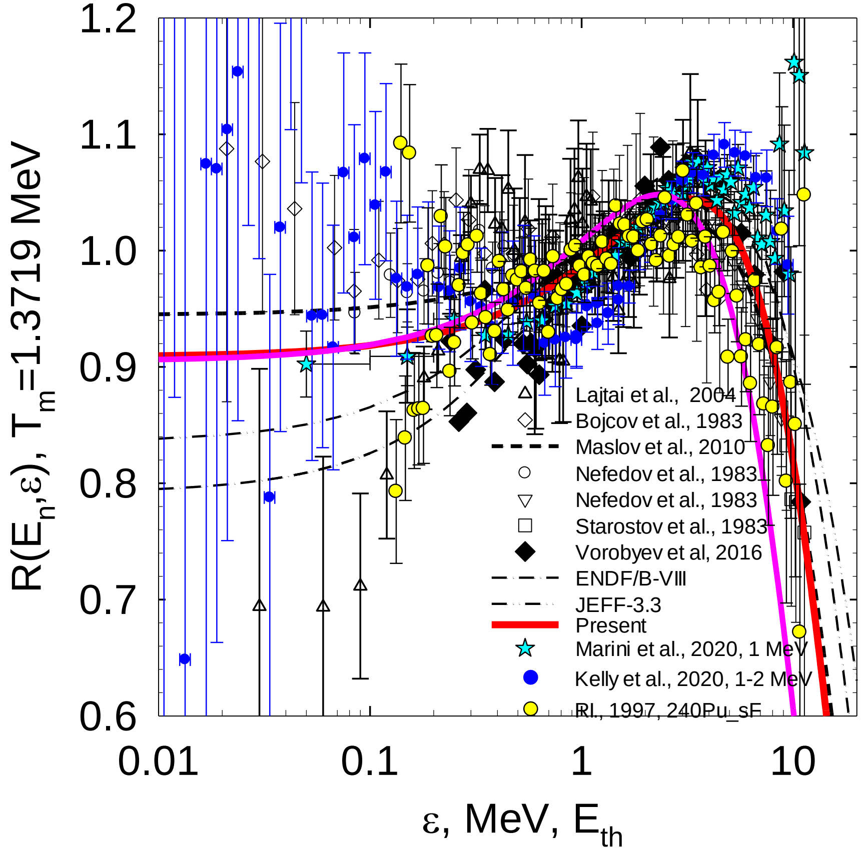
$$E^*_{vij} = \alpha E_{vij}$$

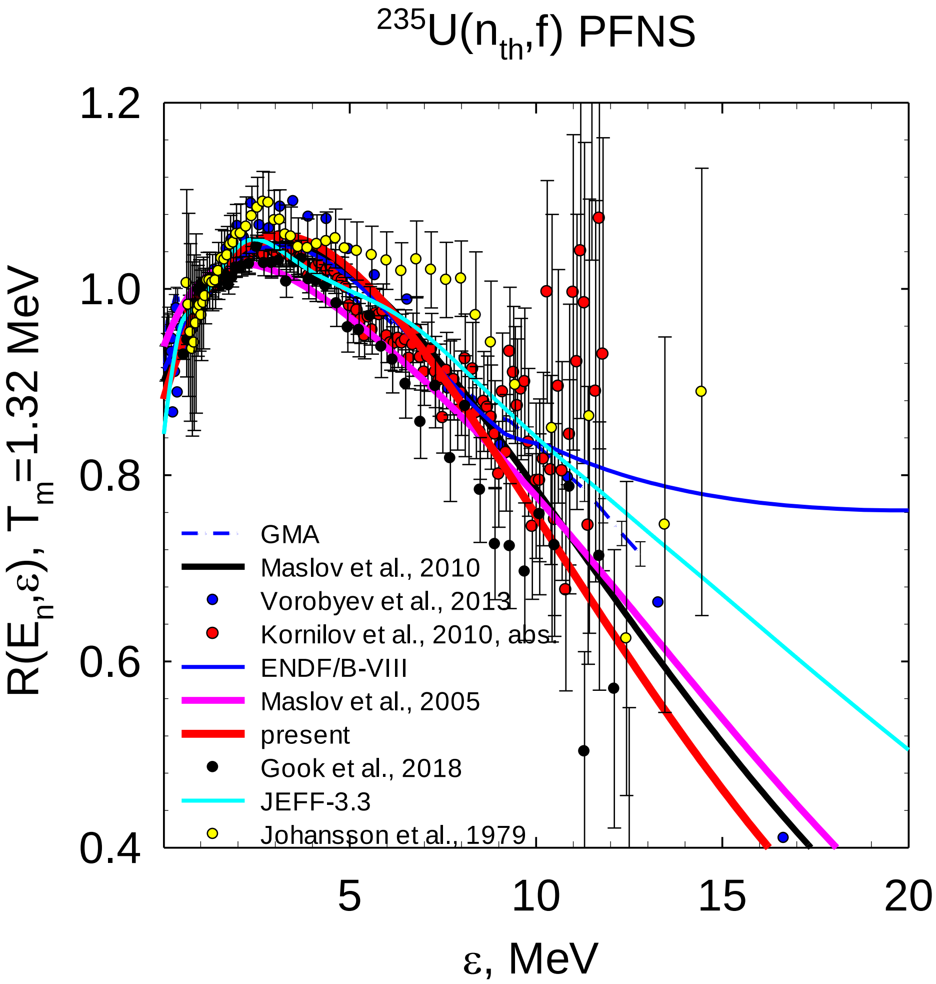

235U(n,F) <E> (ε=0.01-10 MeV)
Kelly et al., 2020
Vorobyev et al., 2016
Kelly et al., 2022
Maslov 2022
ENDF/B-VIII
JEFF-3.3
JENDL-4.0
CENDL
TKE 235U(n,f)
TKE 235U(n,F)
<E>, MeV
NEUTRON ENERGY, MeV
239Pu(n,F) <E> (ε=0.01-10 MeV)
Marini et al., 2020
Kelly et al., 2020
Vorobyev et al., 2016
Maslov, 2022
Maslov, 2022, 0.01-10 MeV
TKE 239Pu(n,F)
TKE 239Pu(n,f)
E_n, MeV
TKE

$^{235}U(n_{th},f)$ PFNS

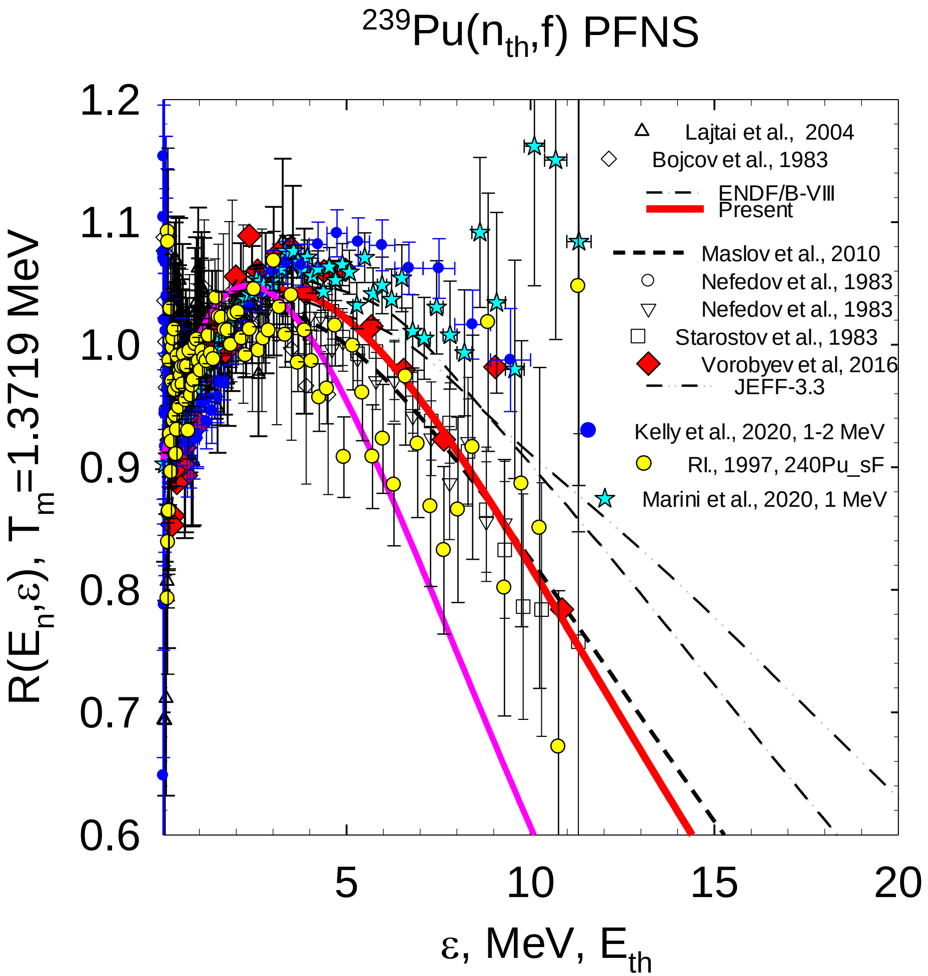


$^{239}Pu(n_{th},f)$ PFNS



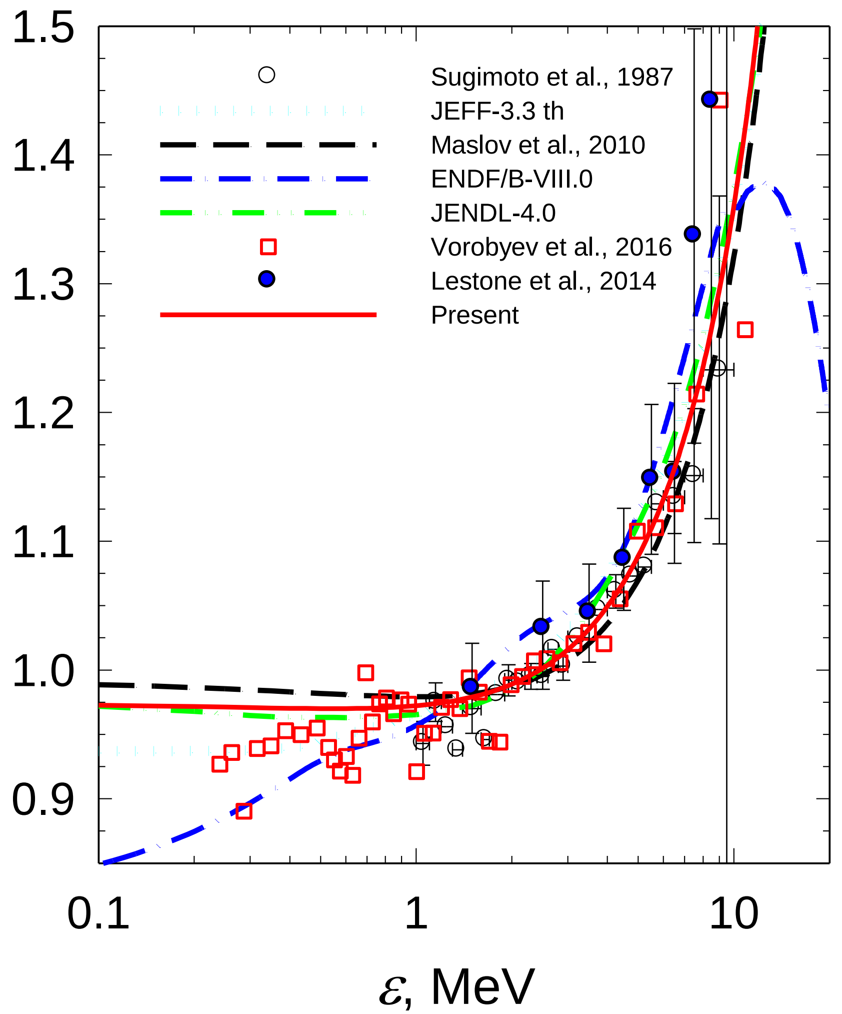


$^{235}U(n_{th},f)$ PFNS
$R(E_n,\varepsilon)$, T_m=1.32 MeV
ε, MeV
1.2
1.0
0.8
0.6
0.4
5
10
15
20
GMA
Maslov et al., 2010
Vorobyev et al., 2013
Kornilov et al., 2010, abs
ENDF/B-VIII
Maslov et al., 2005
present
Gook et al., 2018
JEFF-3.3
Johansson et al., 1979

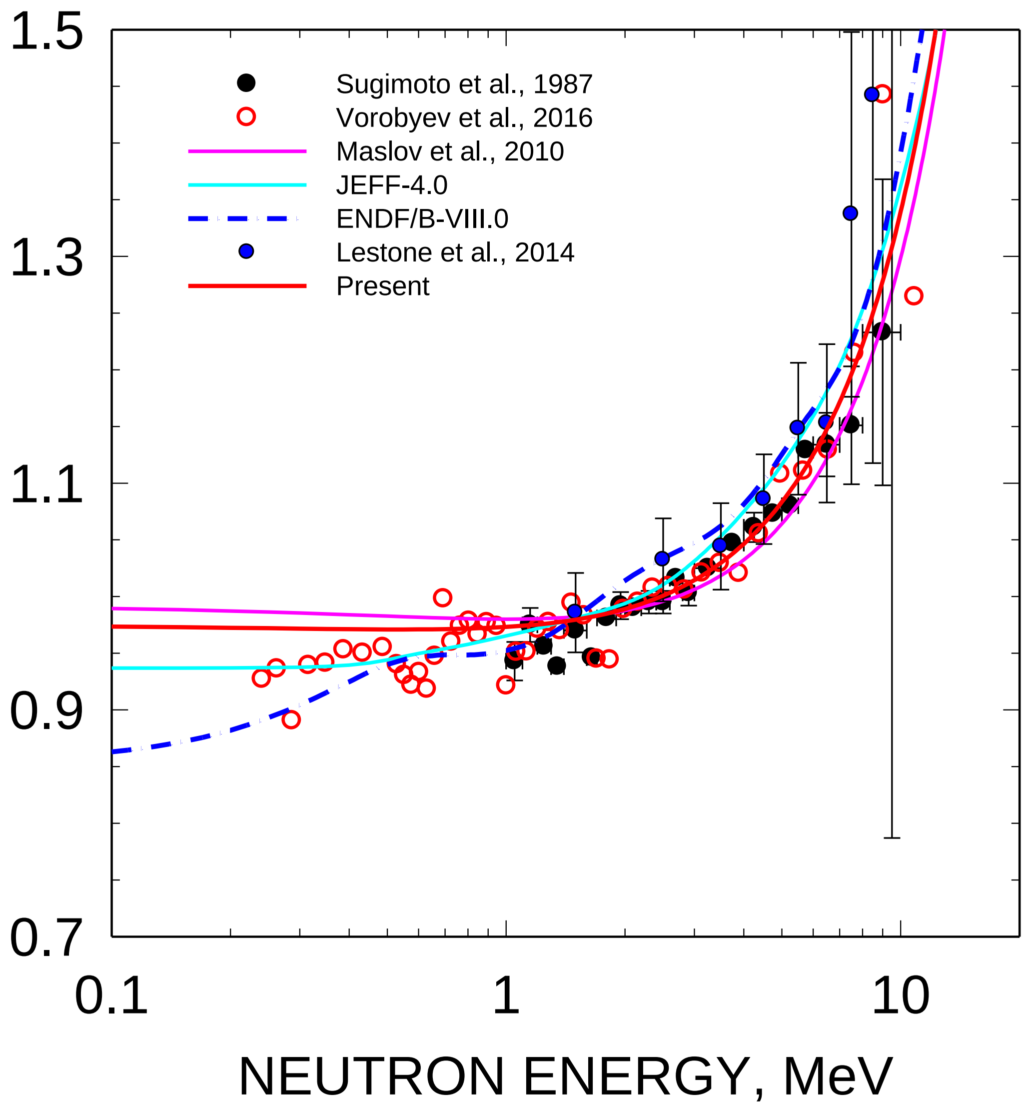


$^{239}Pu(n_{th},f)$ PFNS
$R(E_n,\varepsilon)$, T_m=1.3719 MeV
ε, MeV, E_{th}
1.2
1.1
1.0
0.9
0.8
0.7
0.6
5
10
15
20
Lajtai et al., 2004
Bojcov et al., 1983
ENDF/B-VIII
Present
Maslov et al., 2010
Nefedov et al., 1983
Nefedov et al., 1983
Starostov et al., 1983
Vorobyev et al, 2016
JEFF-3.3
Kelly et al., 2020, 1-2 MeV
RI., 1997, 240Pu_sF
Marini et al., 2020, 1 MeV

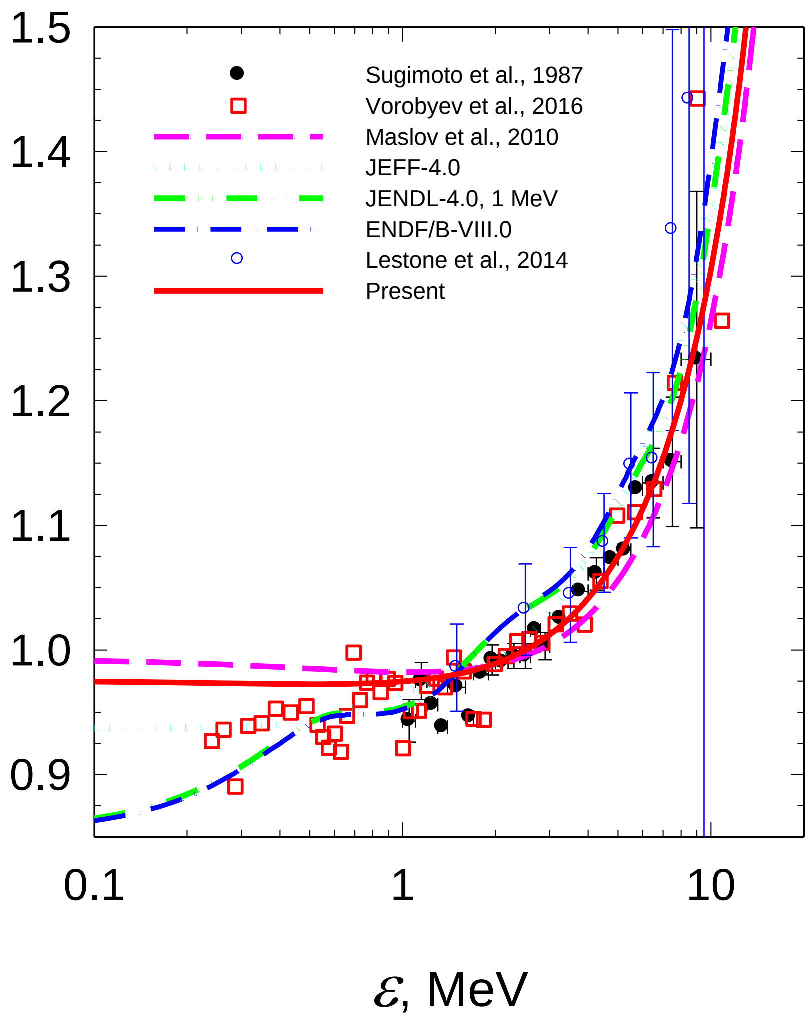
$^{239}Pu/^{235}U$ PFNS ratio, $E_n \sim E_{th}$

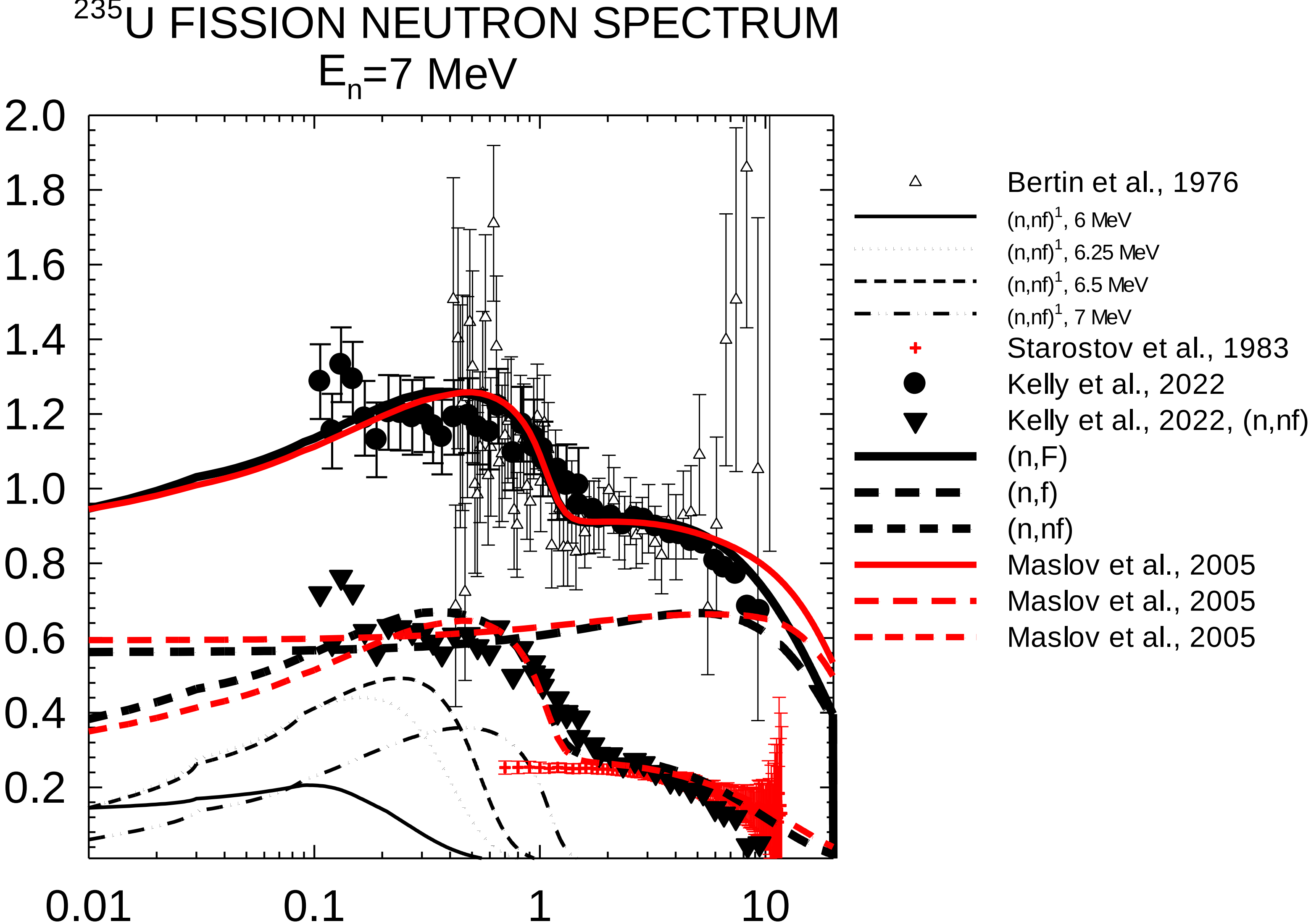


^{239}Pu/^{235}U PFNS ratio, E_n~0.5MeV

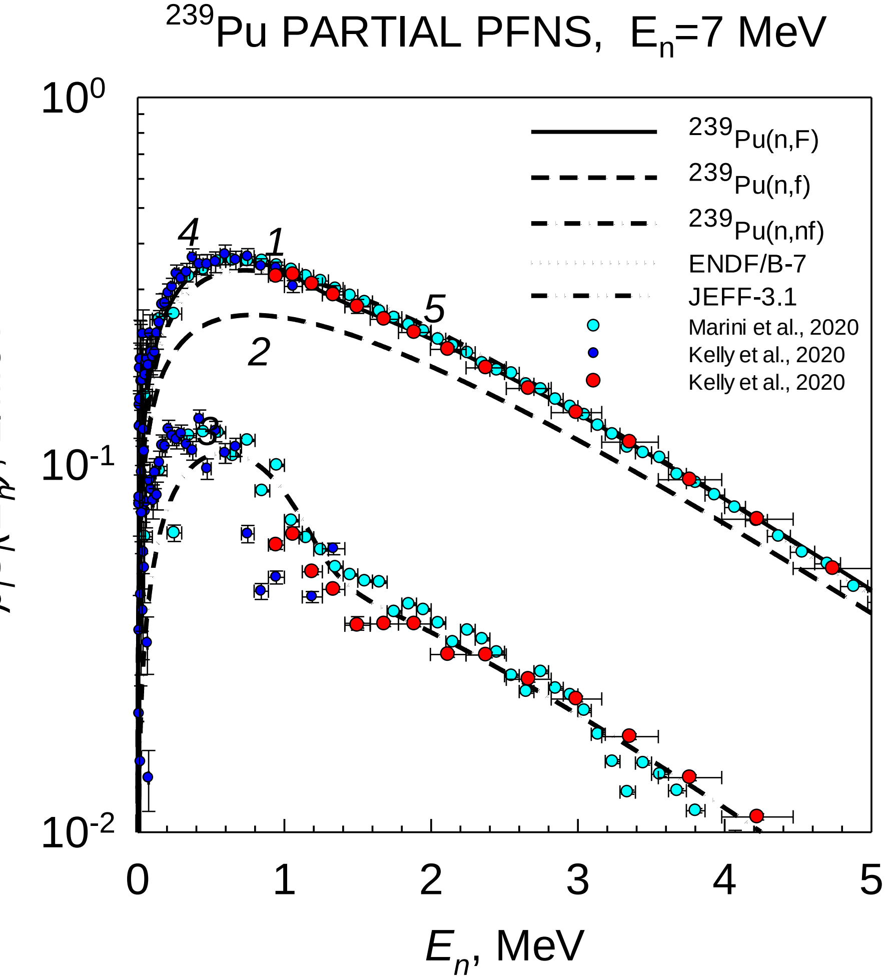


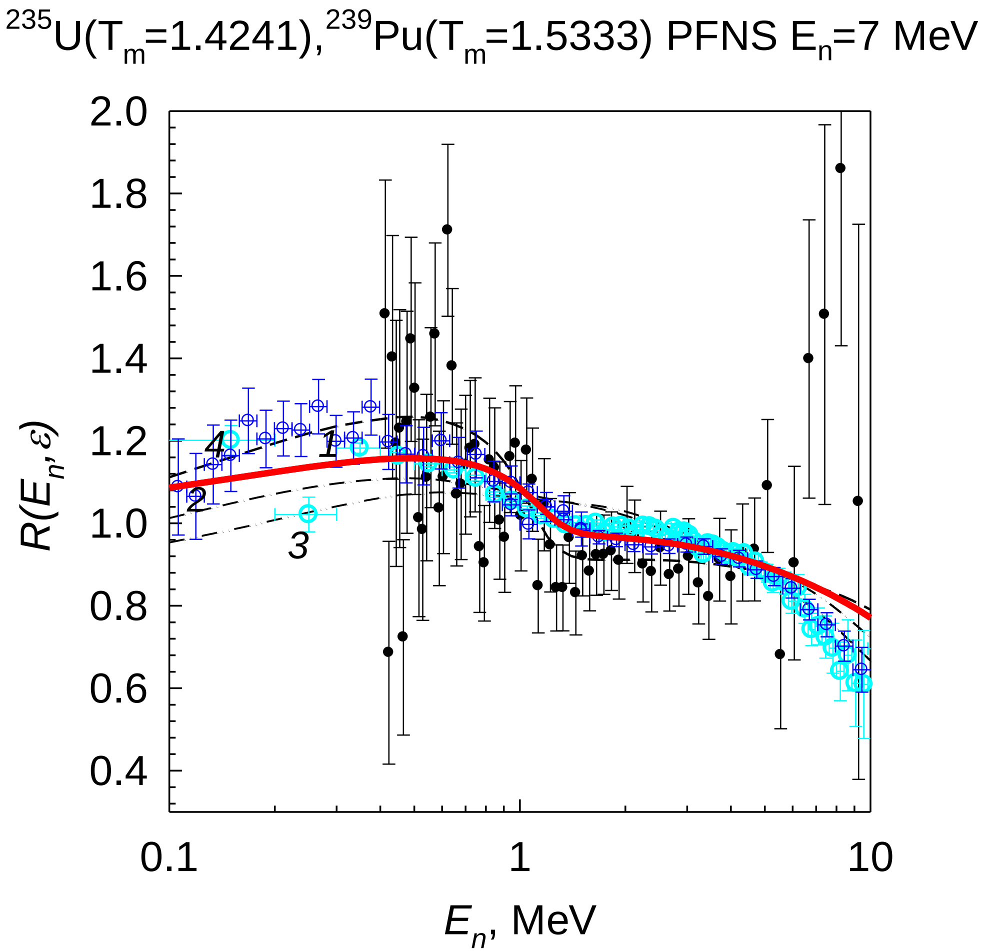
$^{239}Pu/^{235}U$ PFNS ratio, E_n~1.5MeV





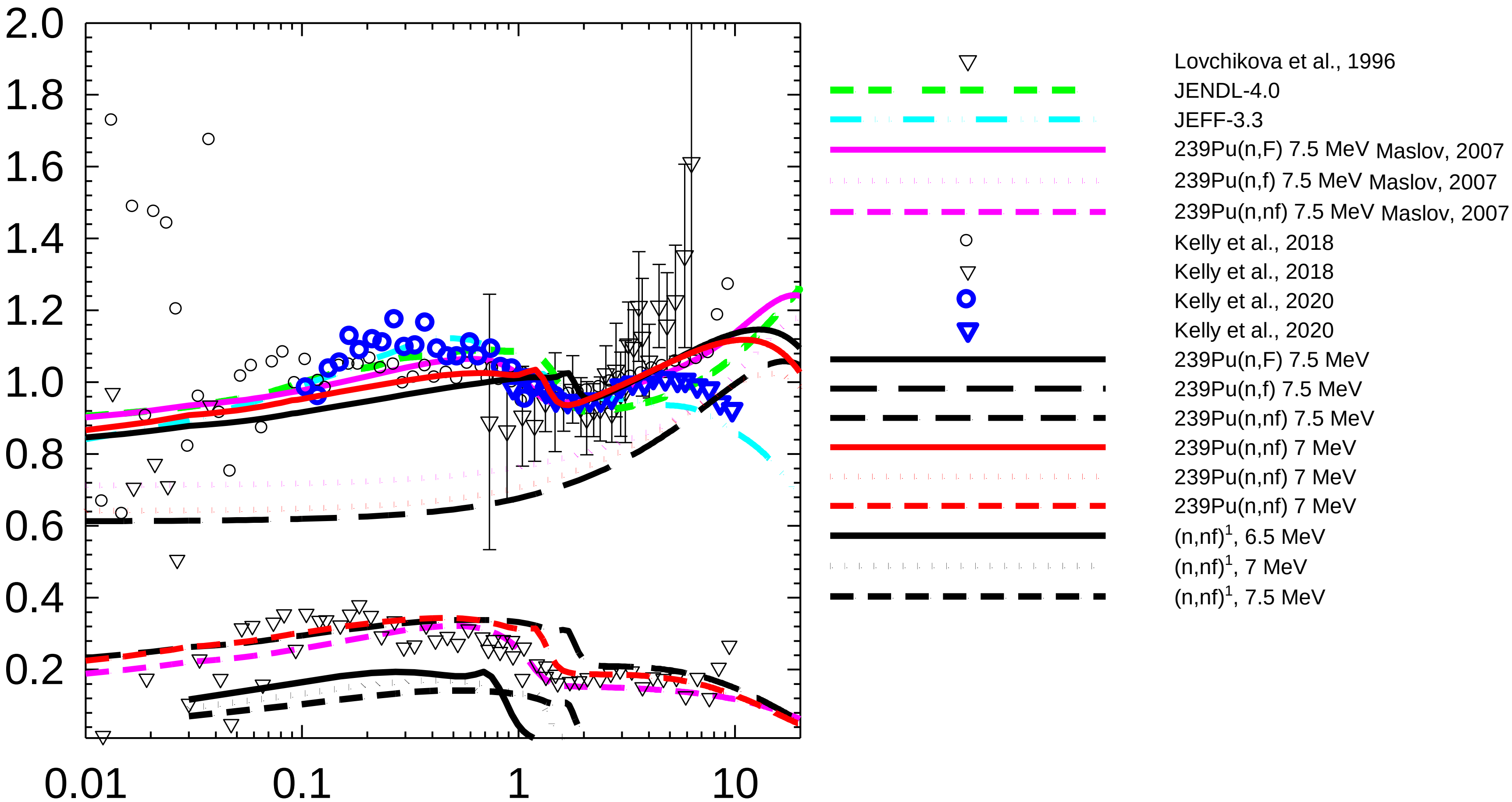
V.M. Maslov et al., Nucl. Phys.A760,274, 2005





V.M. Maslov, Atomnaya Energ. 103, 119,2007

^{239}Pu PFNS E_n=7 (exp.7-8)MeV



V.M. Maslov, Atomnaya Energ. 103, 119,2007

Fission cross section

$$\sigma_{\mathrm{nF}}\left(E_n\right)=\sigma_{\mathrm{nf}}\left(E_n\right)+\sum_{x=1}^{X}\sigma_{\mathrm{n,xnf}}\left(E_n\right)$$

$$\sigma_{\mathrm{n,xnf}}\left(E_n\right)=\sum_{J\pi}^{J}\int_{0}^{U_{\max}}W_{x+1}^{J\pi}(U)P_{f\,(x+1)}^{J\pi}(U)dU$$

Average neutron multiplicity

$$\nu_{\mathrm{p}}(E_n) = \nu_{post} + \nu_{pre} =$$

$$\sum_{x=1}^{X} \nu_{px}(E_{nx}) + \sum_{x=1}^{X} (x-1)\cdot\beta_x(E_n)$$

Prompt-fission neutron spectra

superposition of exclusive pre-fission (n,xnf) spectra and post-fission spectra
$S_{A+2-x}(\varepsilon, E_n)$

$$
\begin{aligned}
\mathrm{S}(\varepsilon,\mathrm{E_n}) = {} & \nu^{-1}(E_n)(\nu_1(E_n)\beta_1(E_n)\mathrm{S}_{\mathrm{A+1}}(\varepsilon,\mathrm{E_n}) + \\
& \nu_2(E_n)\beta_2(E_n)\mathrm{S}_A(\varepsilon,\mathrm{E_n}) + \beta_2(E_n)\frac{d\sigma^1_{\mathrm{nnnf}}(E_n)}{d\varepsilon} + \\
& \nu_3(E_n)\beta_3(E_n)\mathrm{S}_{A-1}(\varepsilon,\mathrm{E_n}) + \beta_3(E_n)\left(\frac{d\sigma^1_{\mathrm{n2nnf}}(E_n)}{d\varepsilon} + \frac{d\sigma^2_{\mathrm{n2nnf}}(E_n)}{d\varepsilon}\right) + \\
& \nu_4(E_n)\beta_4(E_n)\mathrm{S}_{A-2}(\varepsilon,\mathrm{E_n}) + \beta_4(E_n)\left(\frac{d\sigma^1_{\mathrm{n3nnf}}(E_n)}{d\varepsilon} + \frac{d\sigma^2_{\mathrm{n3nnf}}(E_n)}{d\varepsilon} + \frac{d\sigma^3_{\mathrm{n3nnf}}(E_n)}{d\varepsilon}\right))
\end{aligned}
$$

$$d\sigma^{1}_{nnx}/d\varepsilon \approx d\tilde{\sigma}^{1}_{nnx}/d\varepsilon + \sqrt{\frac{\varepsilon}{E_n}}\,\frac{\omega(\theta)}{E_n-\varepsilon}$$

$$\frac{d\sigma^{1}_{n2nx}}{d\varepsilon} = \frac{d\sigma^{1}_{nnx}(\varepsilon)}{d\varepsilon}\,\frac{\Gamma^{A}_{n}(E_n-\varepsilon)}{\Gamma^{A}(E_n-\varepsilon)}$$

$$\frac{d\sigma^{1}_{n2nx}}{d\varepsilon} = \frac{d\sigma^{1}_{nnx}(\varepsilon)}{d\varepsilon}\,\frac{\Gamma^{A}_{n}(E_n-\varepsilon)}{\Gamma^{A}(E_n-\varepsilon)}$$

$$\frac{d\sigma^{1}_{n2nf}}{d\varepsilon} = \int_{0}^{E-B_n-\varepsilon} \frac{d\sigma^{1}_{n2nx}(\varepsilon)}{d\varepsilon}\,\frac{\Gamma^{A-1}_{f}(E_n-B^{A}_{n}-\varepsilon-\varepsilon_1)}{\Gamma^{A-1}(E_n-B^{A}_{n}-\varepsilon-\varepsilon_1)}\,d\varepsilon_1$$

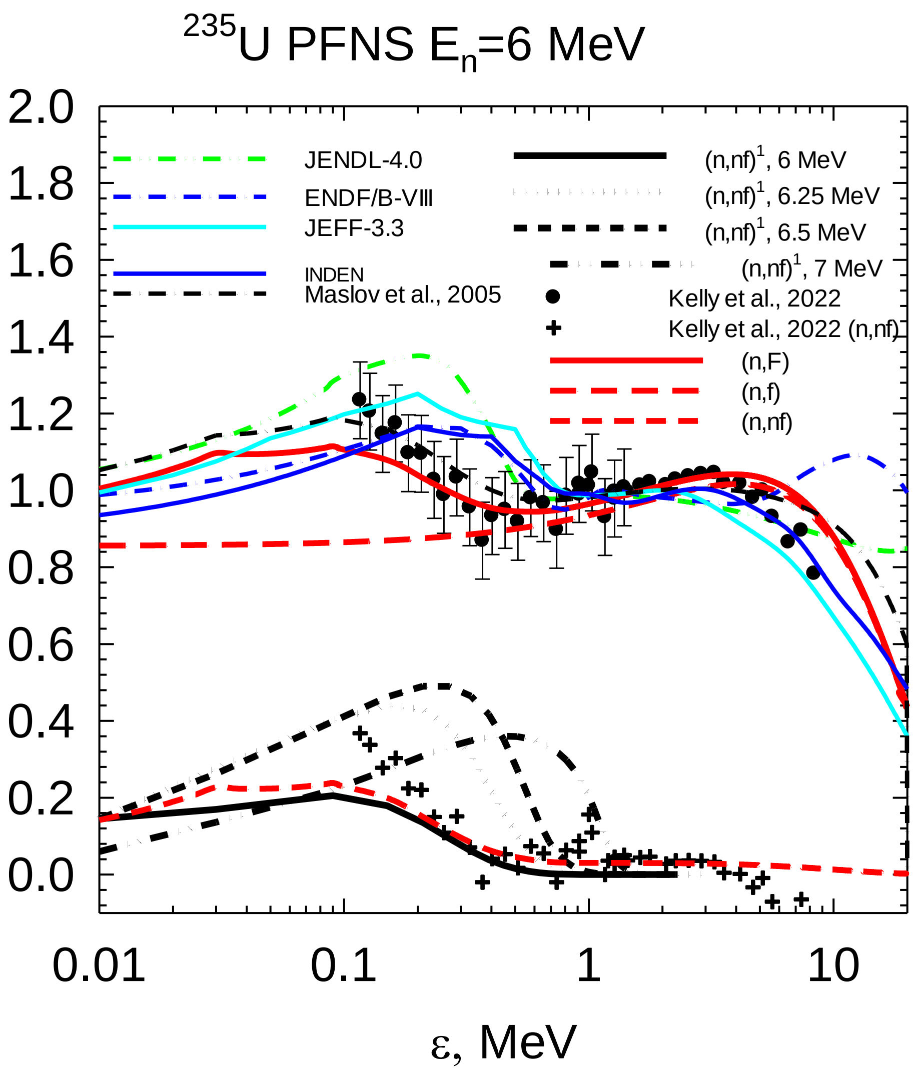
$$\frac{d\sigma^2_{n2nx}}{d\varepsilon} = \int_0^{E-B_n^A-\varepsilon} \frac{d\sigma^1_{n2nx}(\varepsilon)}{d\varepsilon} \frac{\Gamma_n^A(E_n - B_n^A - \varepsilon - \varepsilon_1)}{\Gamma^A(E_n - B_n^A - \varepsilon - \varepsilon_1)} d\varepsilon_1$$

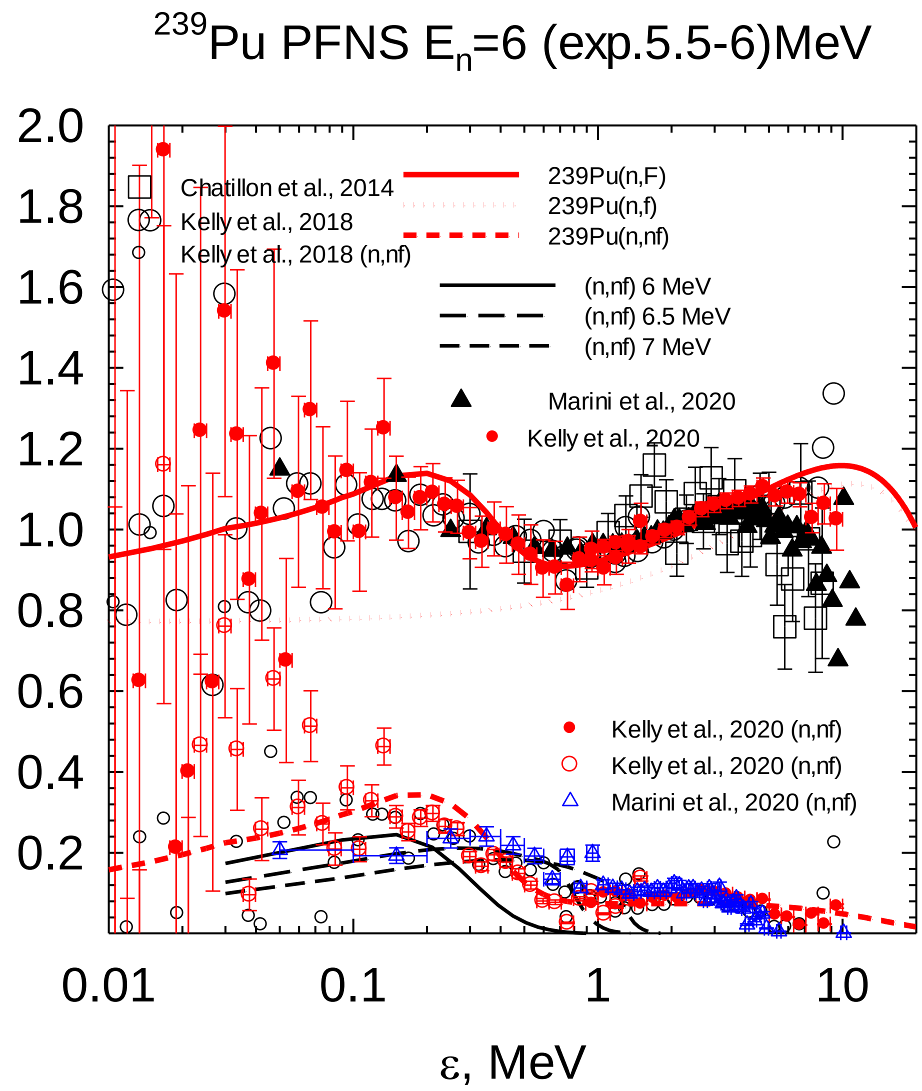
$$\frac{d\sigma^2_{n2nf}}{d\varepsilon} = \int_0^{E-B_n} \frac{d\sigma^2_{n2nx}(\varepsilon)}{d\varepsilon} \frac{\Gamma_f^{A-1}(E_n - B_n^A - \varepsilon_1 - \varepsilon_2)}{\Gamma^{A-1}(E_n - B_n^A - \varepsilon_1 - \varepsilon_2)} d\varepsilon_1$$

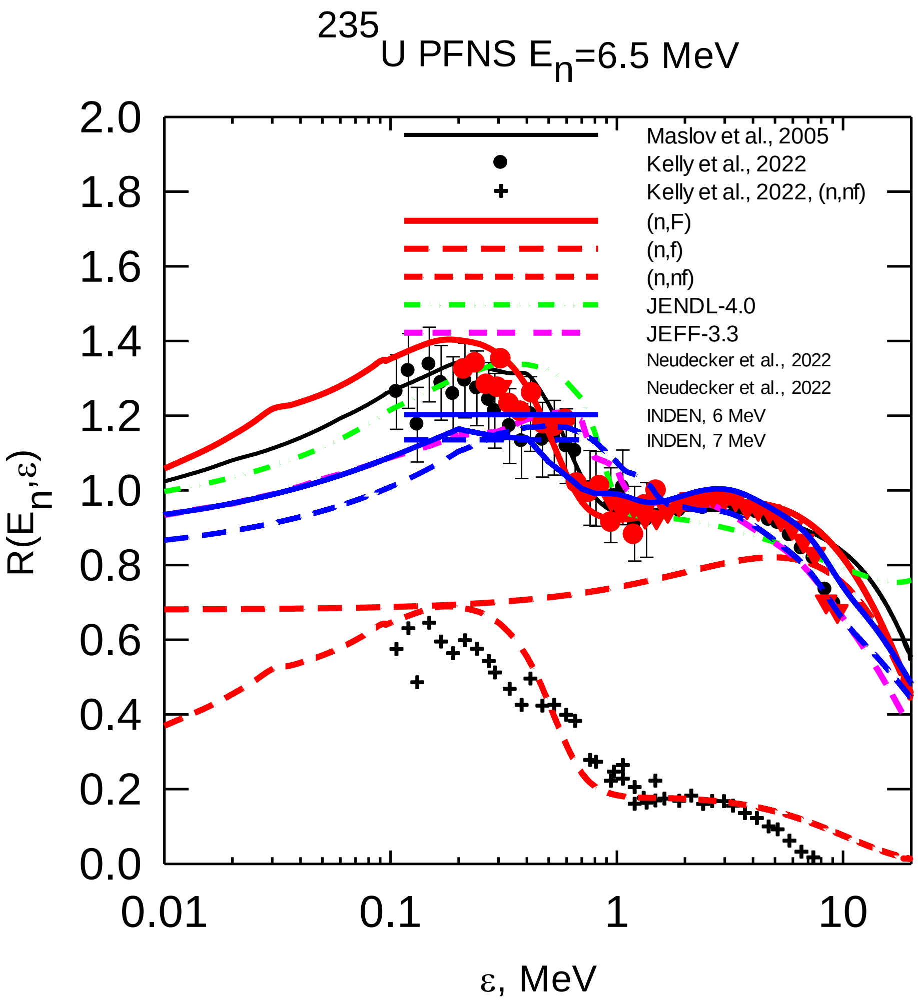
$$E_f^{post} \approx E_f^{pre}\left(1-\nu_{post}/\left(A-\nu_{pre}\right)\right)$$

$$E_f^{pre}(E_n)=\sum_{x=0}^{X} E_{fx}^{pre}(E_{nx})\cdot\sigma_{n,xnf}/\sigma_{n,F},$$

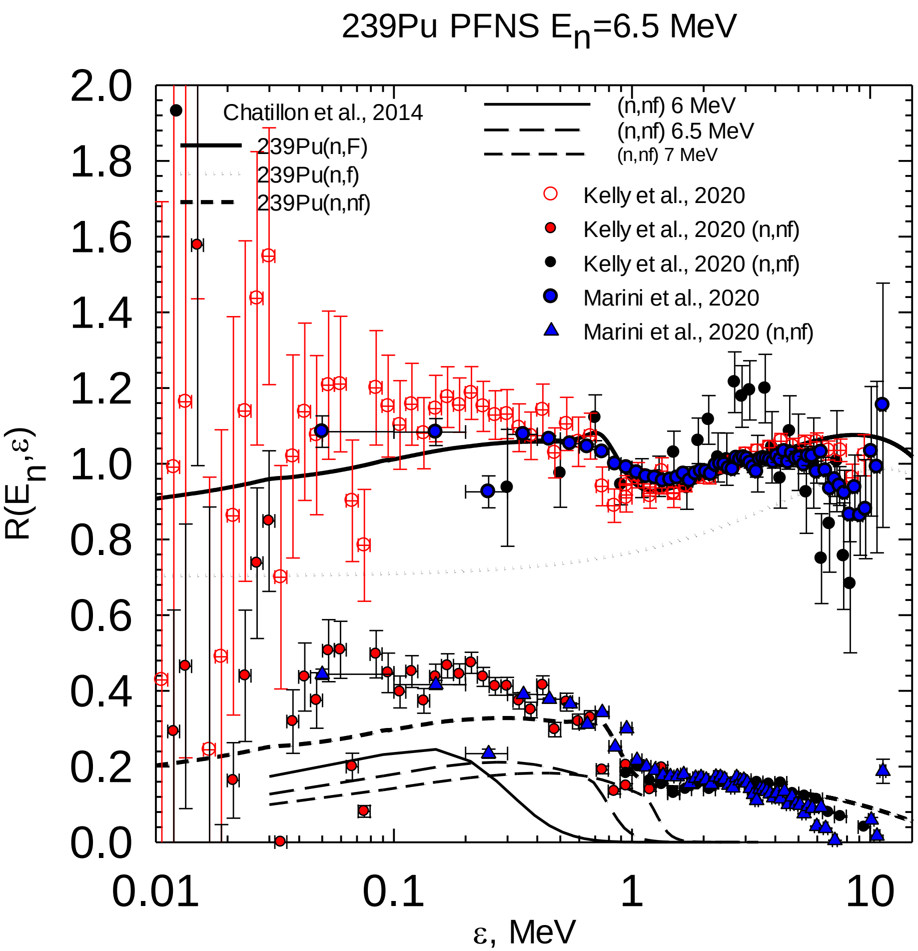
$$E_{nx}=E_n+B_n-\sum_{x=0,1\le j\le x}^{X}\left(\left\langle E_{n,xnf}^{j}\right\rangle+B_x\right)$$


235U PFNS En=6 MeV
JENDL-4.0
ENDF/B-VIII
JEFF-3.3
INDEN
Maslov et al., 2005
(n,nf)1, 6 MeV
(n,nf)1, 6.25 MeV
(n,nf)1, 6.5 MeV
(n,nf)1, 7 MeV
Kelly et al., 2022
Kelly et al., 2022 (n,nf)
(n,F)
(n,f)
(n,nf)
ε, MeV

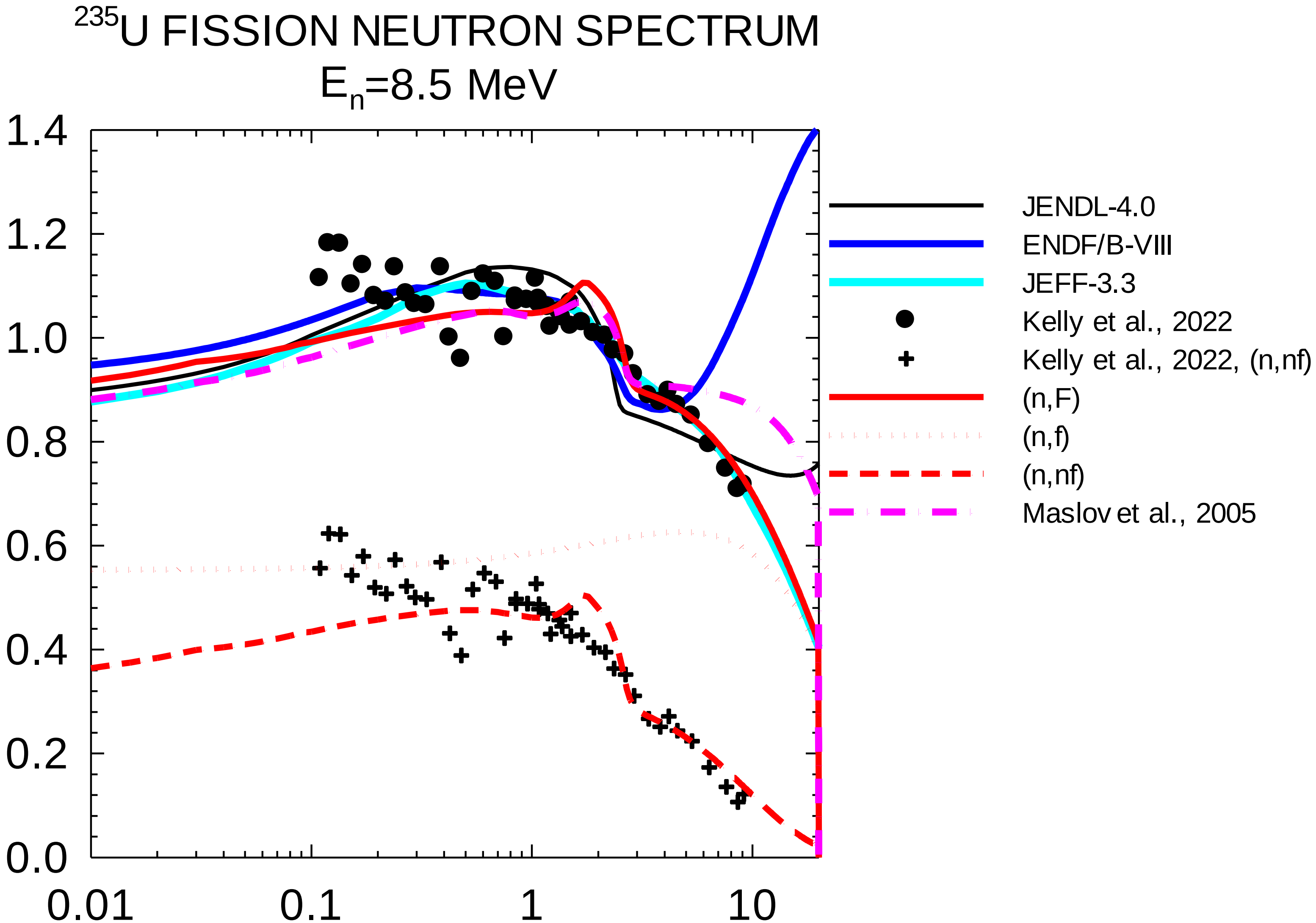

239Pu PFNS En=6 (exp.5.5-6)MeV
Chatillon et al., 2014
Kelly et al., 2018
Kelly et al., 2018 (n,nf)
239Pu(n,F)
239Pu(n,f)
239Pu(n,nf)
(n,nf) 6 MeV
(n,nf) 6.5 MeV
(n,nf) 7 MeV
Marini et al., 2020
Kelly et al., 2020
Kelly et al., 2020 (n,nf)
Kelly et al., 2020 (n,nf)
Marini et al., 2020 (n,nf)
ε, MeV

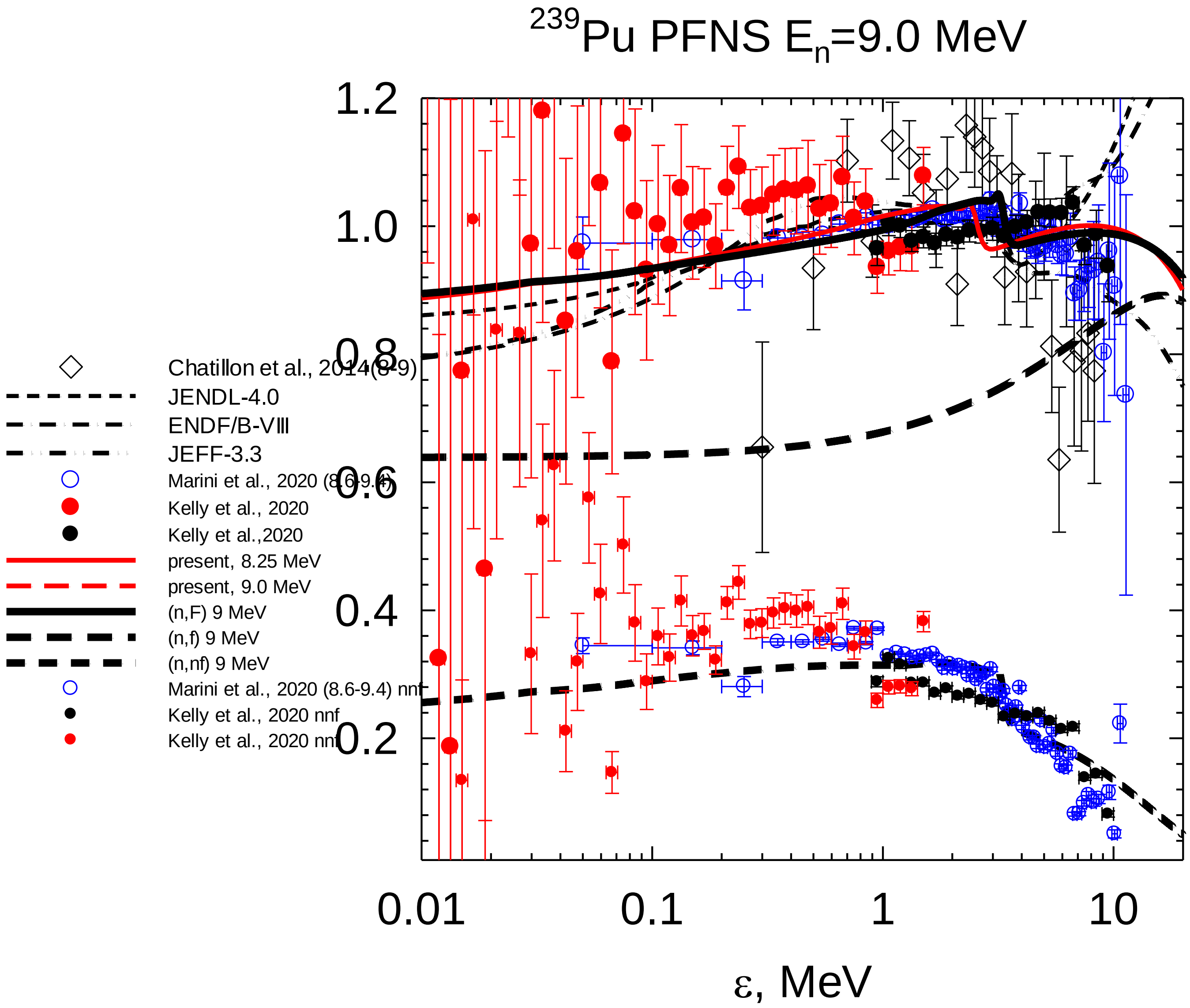


235U PFNS En=6.5 MeV
R(En,ε)
ε, MeV
Maslov et al., 2005
Kelly et al., 2022
Kelly et al., 2022, (n,nf)
(n,F)
(n,f)
(n,nf)
JENDL-4.0
JEFF-3.3
Neudecker et al., 2022
Neudecker et al., 2022
INDEN, 6 MeV
INDEN, 7 MeV

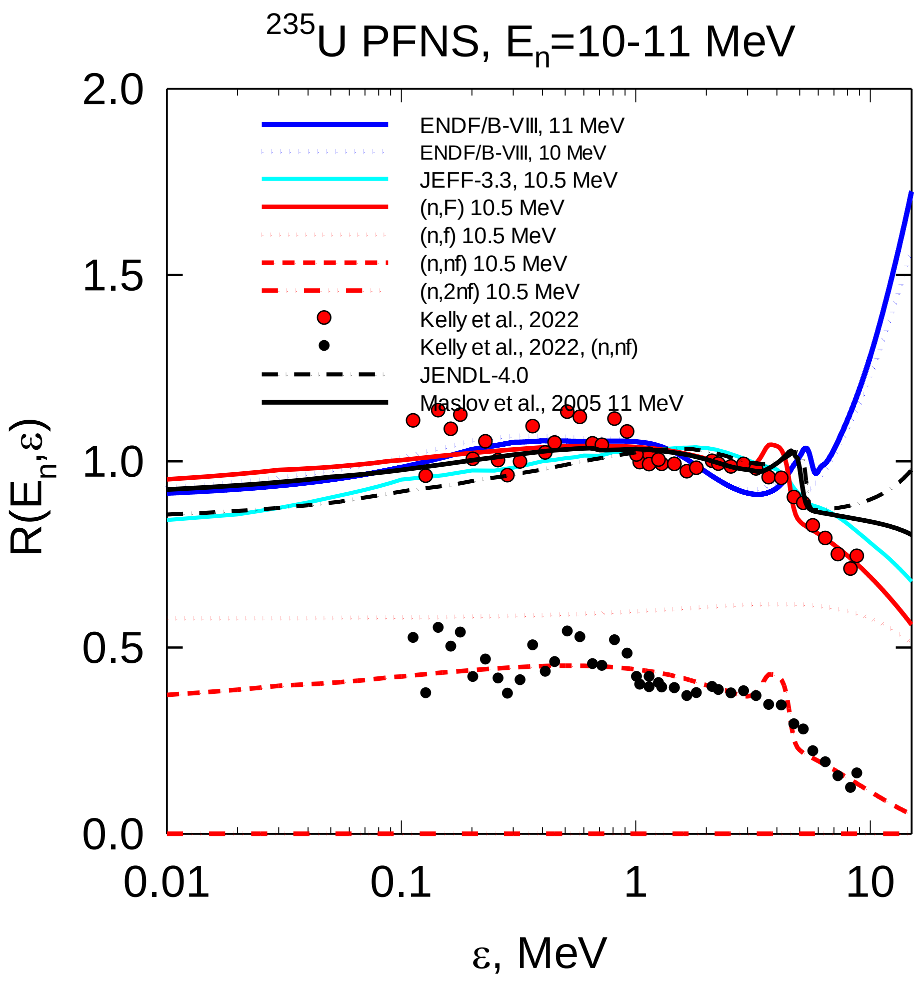


239Pu PFNS En=6.5 MeV
R(En,ε)
ε, MeV
Chatillon et al., 2014
239Pu(n,F)
239Pu(n,f)
239Pu(n,nf)
(n,nf) 6 MeV
(n,nf) 6.5 MeV
(n,nf) 7 MeV
Kelly et al., 2020
Kelly et al., 2020 (n,nf)
Kelly et al., 2020 (n,nf)
Marini et al., 2020
Marini et al., 2020 (n,nf)

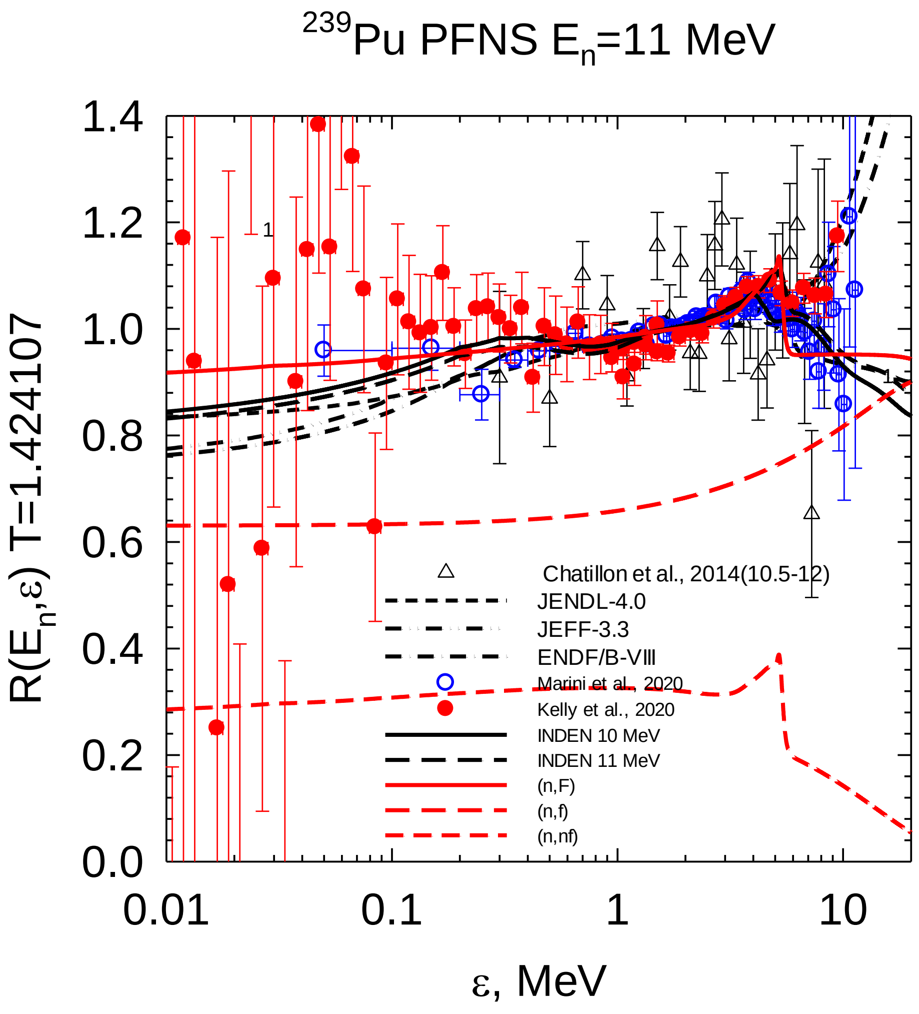

235U FISSION NEUTRON SPECTRUM
En=8.5 MeV
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.01
0.1
1
10
JENDL-4.0
ENDF/B-VIII
JEFF-3.3
Kelly et al., 2022
Kelly et al., 2022, (n,nf)
(n,F)
(n,f)
(n,nf)
Maslov et al., 2005



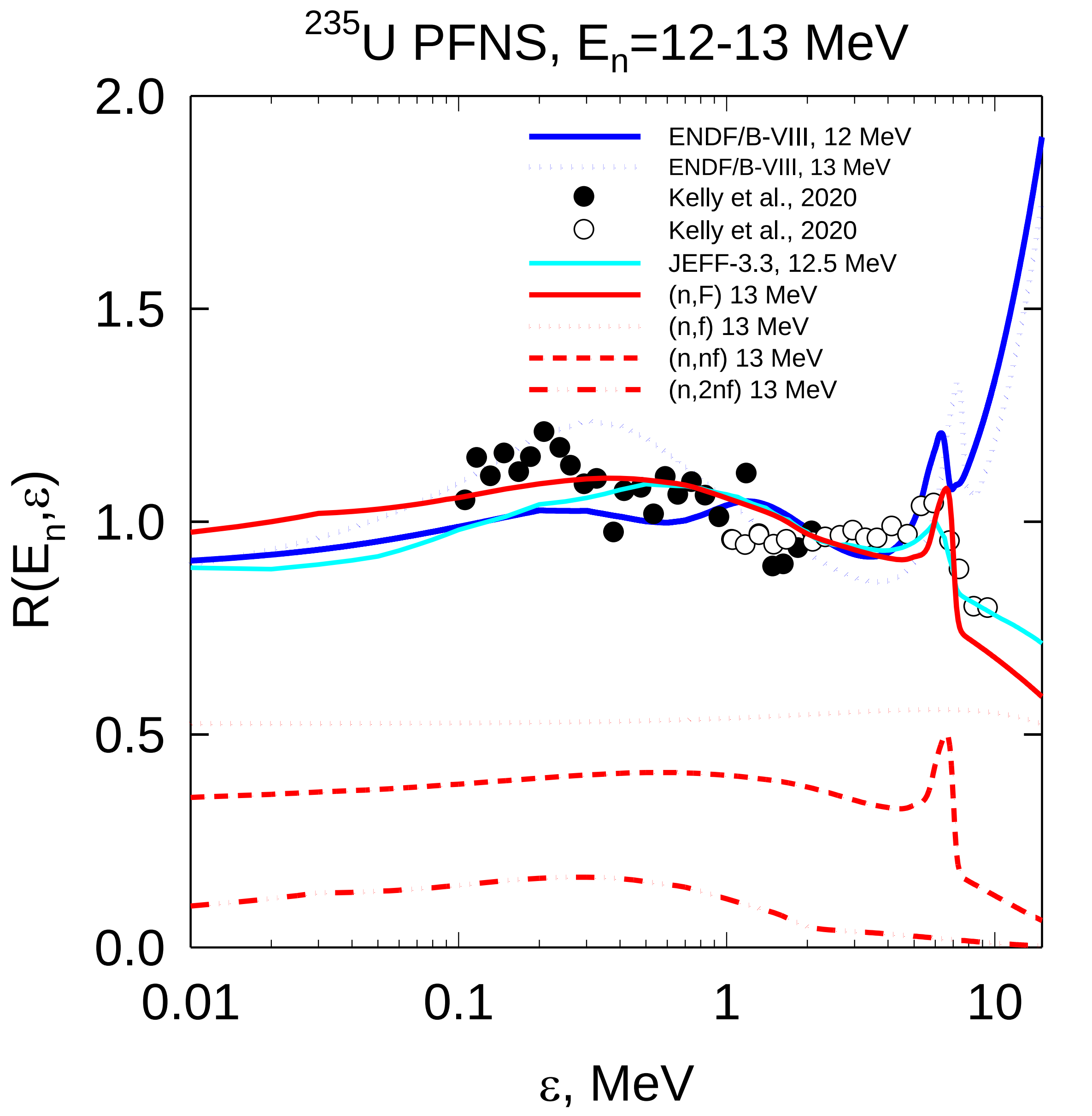
^{239}Pu PFNS E_n=9.0 MeV
1.2
1.0
0.8
0.6
0.4
0.2
0.01
0.1
1
10
ε, MeV
Chatillon et al., 2014(8-9)
JENDL-4.0
ENDF/B-VIII
JEFF-3.3
Marini et al., 2020 (8.6-9.4)
Kelly et al., 2020
Kelly et al.,2020
present, 8.25 MeV
present, 9.0 MeV
(n,F) 9 MeV
(n,f) 9 MeV
(n,nf) 9 MeV
Marini et al., 2020 (8.6-9.4) nnf
Kelly et al., 2020 nnf
Kelly et al., 2020 nnf



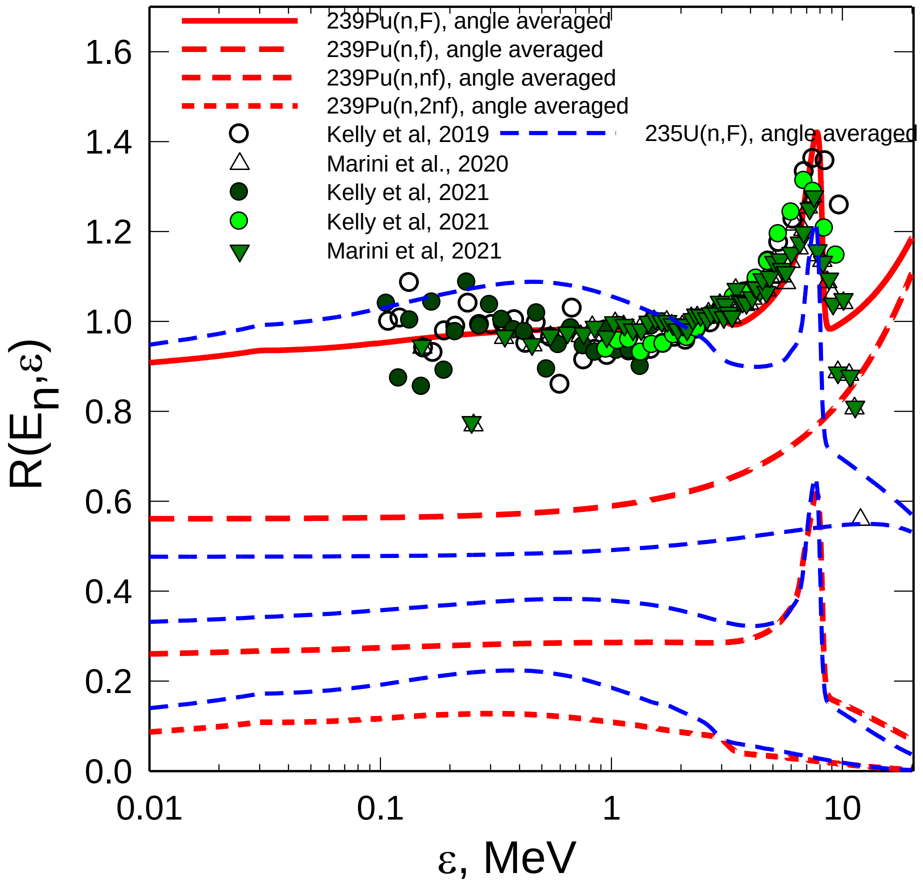
^{235}U PFNS, E_n=10-11 MeV
ENDF/B-VIII, 11 MeV
ENDF/B-VIII, 10 MeV
JEFF-3.3, 10.5 MeV
(n,F) 10.5 MeV
(n,f) 10.5 MeV
(n,nf) 10.5 MeV
(n,2nf) 10.5 MeV
Kelly et al., 2022
Kelly et al., 2022, (n,nf)
JENDL-4.0
Maslov et al., 2005 11 MeV
R(E$_n$,ε)
ε, MeV



^{239}Pu PFNS E_n=11 MeV
Chatillon et al., 2014(10.5-12)
JENDL-4.0
JEFF-3.3
ENDF/B-VIII
Marini et al., 2020
Kelly et al., 2020
INDEN 10 MeV
INDEN 11 MeV
(n,F)
(n,f)
(n,nf)
R(E$_n$,ε) T=1.424107
ε, MeV

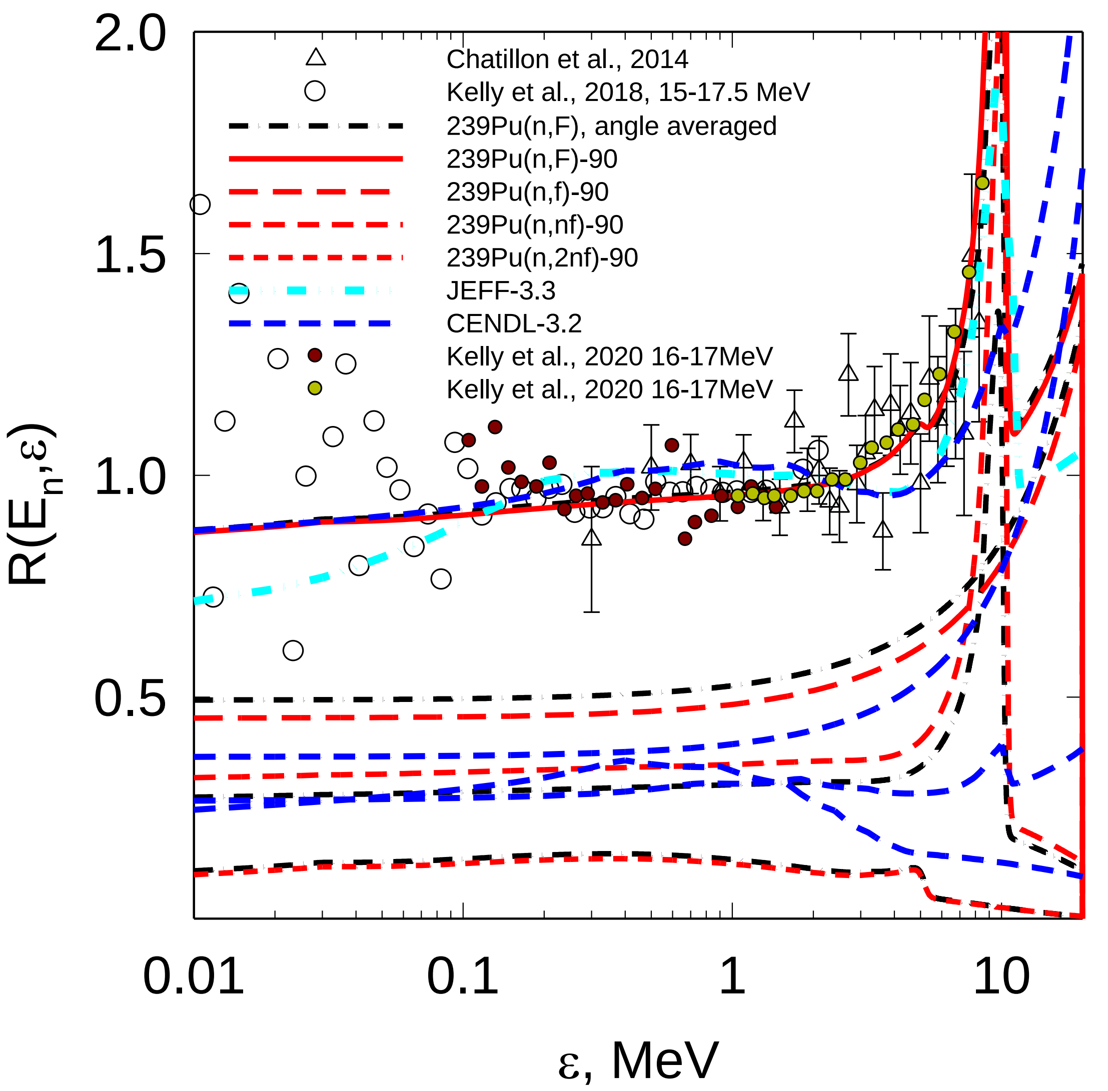

^{235}U PFNS, E_n=12-13 MeV
2.0
1.5
1.0
0.5
0.0
R(E_n,ε)
0.01
0.1
1
10
ε, MeV
ENDF/B-VIII, 12 MeV
ENDF/B-VIII, 13 MeV
Kelly et al., 2020
Kelly et al., 2020
JEFF-3.3, 12.5 MeV
(n,F) 13 MeV
(n,f) 13 MeV
(n,nf) 13 MeV
(n,2nf) 13 MeV

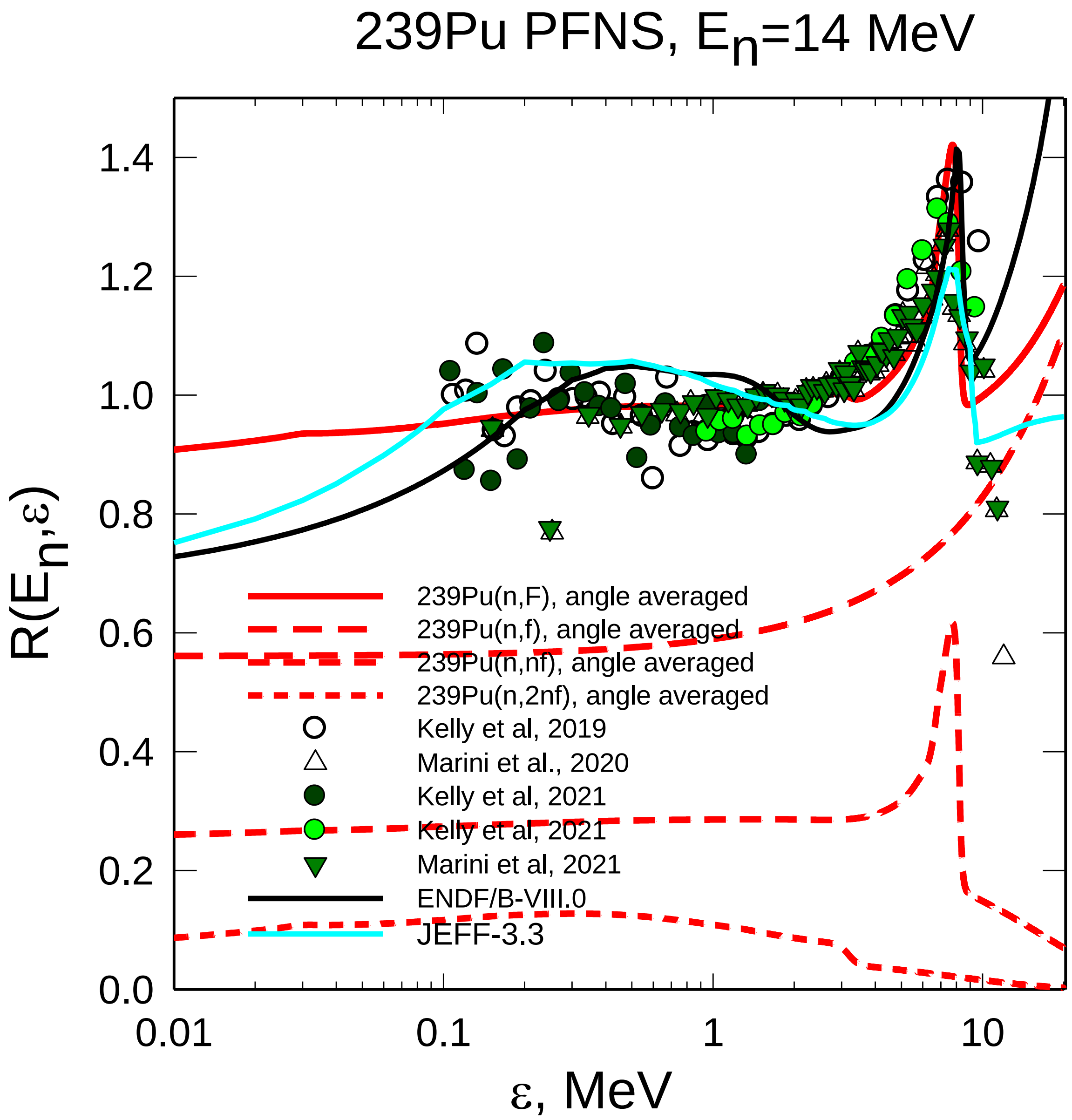
239Pu PFNS, E_n=14 MeV



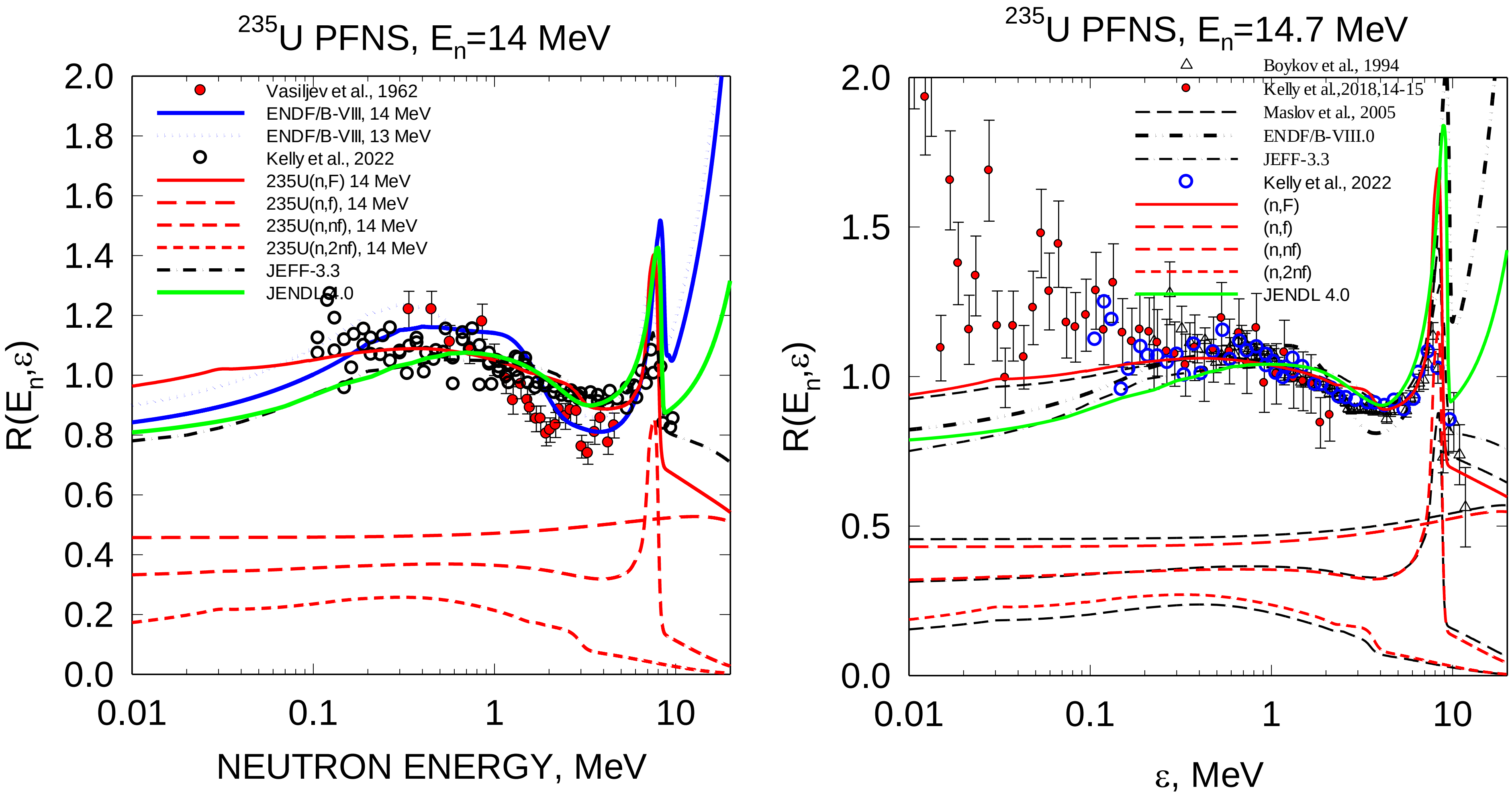
V.M. Maslov, Atomnaya Energ. 103, 119,2007

^{239}Pu PFNS, E_n=16 MeV



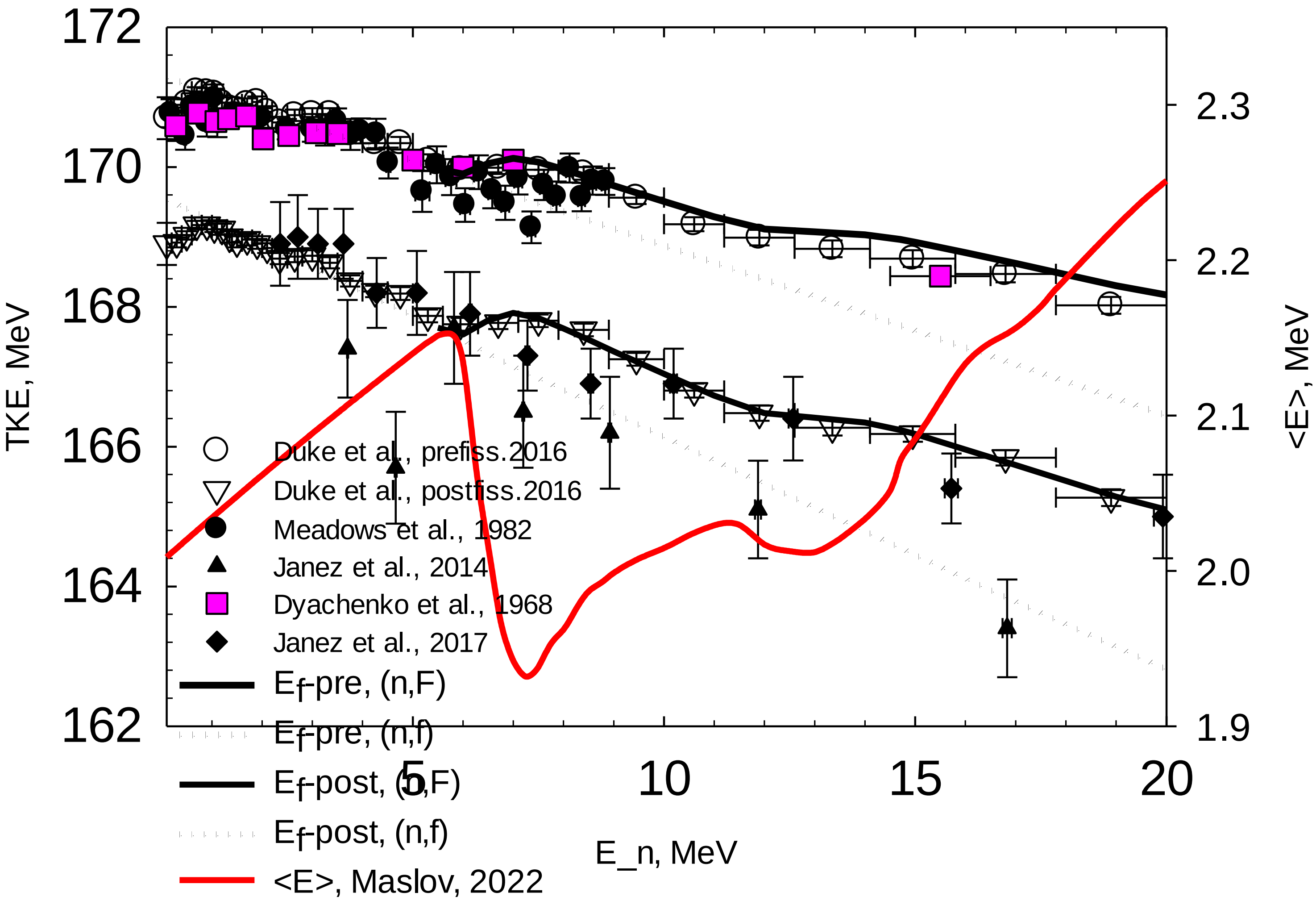


239Pu PFNS, E_n=14 MeV
R(E_n,ε)
ε, MeV
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.01
0.1
1
10
239Pu(n,F), angle averaged
239Pu(n,f), angle averaged
239Pu(n,nf), angle averaged
239Pu(n,2nf), angle averaged
Kelly et al, 2019
Marini et al., 2020
Kelly et al, 2021
Kelly et al, 2021
Marini et al, 2021
ENDF/B-VIII.0
JEFF-3.3

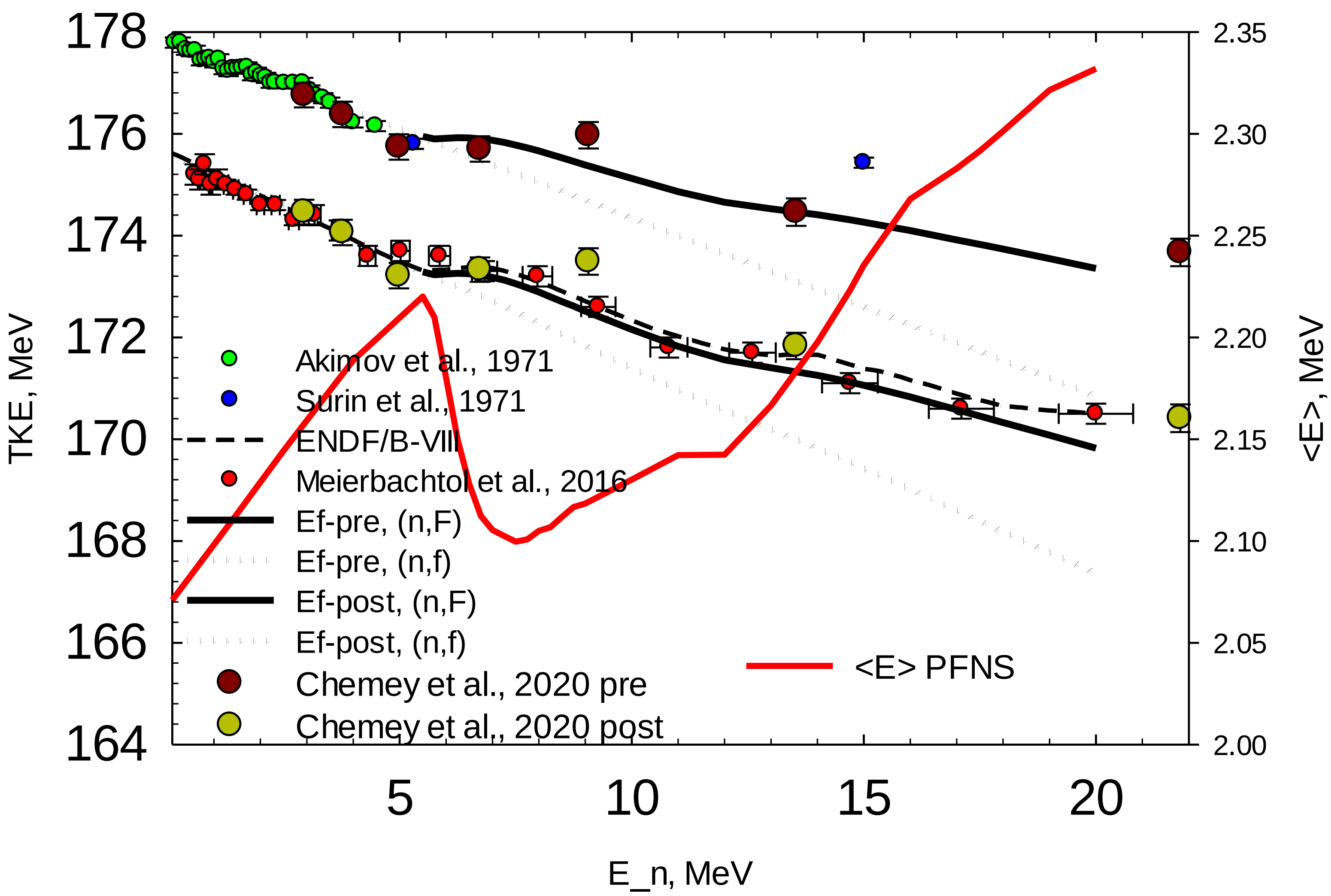


235U PFNS, En=14 MeV
Vasiljev et al., 1962
ENDF/B-VIII, 14 MeV
ENDF/B-VIII, 13 MeV
Kelly et al., 2022
235U(n,F) 14 MeV
235U(n,f), 14 MeV
235U(n,nf), 14 MeV
235U(n,2nf), 14 MeV
JEFF-3.3
JENDL-4.0
R(En,ε)
NEUTRON ENERGY, MeV
235U PFNS, En=14.7 MeV
Boykov et al., 1994
Kelly et al.,2018,14-15
Maslov et al., 2005
ENDF/B-VIII.0
JEFF-3.3
Kelly et al., 2022
(n,F)
(n,f)
(n,nf)
(n,2nf)
JENDL 4.0
R(En,ε)
ε, MeV

235U(n,F), TKE, MeV



239Pu(n,F), TKE, MeV



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A. Chatillon et al., Phys. Rev. C89, 014611 (2014).

B. K. J. Kelly, J.A. Gomez, e. a. Phys. Rev., 2022, v. C 105, p. 044615

Fissile targets Prompt Fission Neutron Spectra

Asymmetry of first neutron emission in 239Pu(n,nγ) En=14 MeV
Kammerdiener J.L., UCRL-51232, 1972.

Asymmetry of pre-fission neutron emission
Kelly e. a., Phys. Rev. Lett., 2019, v. 122, p. 072503

(n,xnf) fission neutron asymmetry at En>12 MeV
Asymmetry of first neutron emission in 238U(n,nγ) En=14 -18 MeV
Baba M. et al., 1990

Emissive neutron spectra

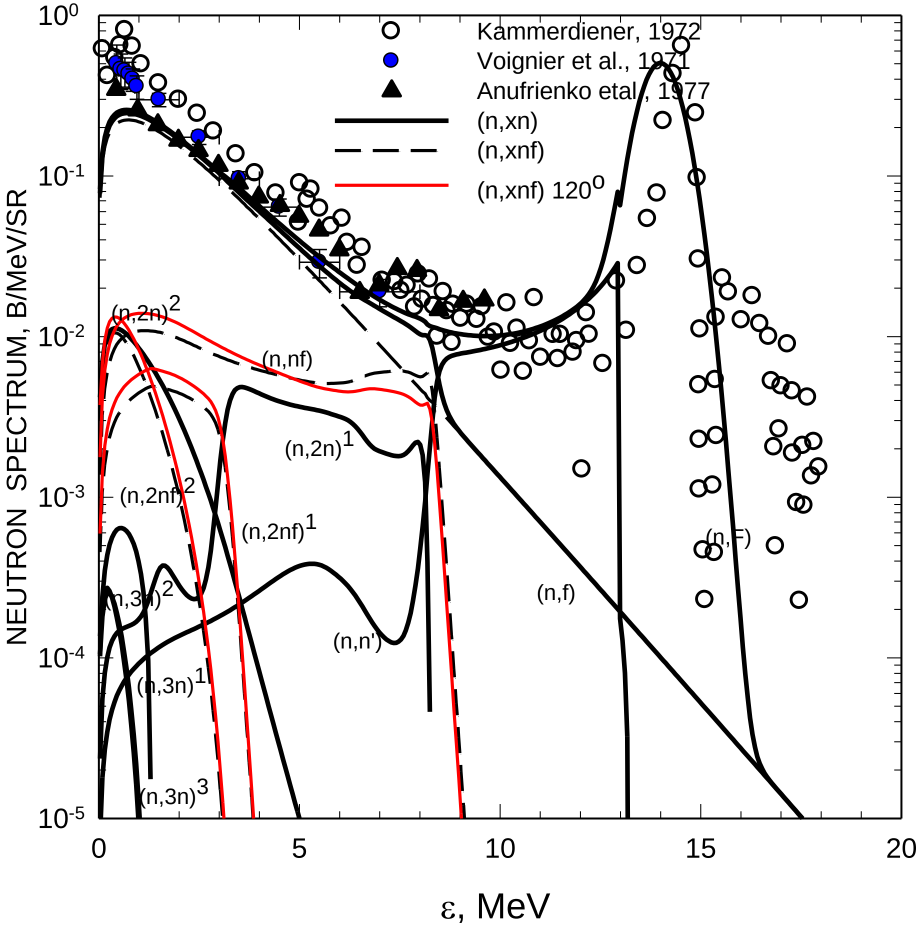
superposition of exclusive (n,xn) spectra and fission spectra $S_F(\varepsilon, E_n)$

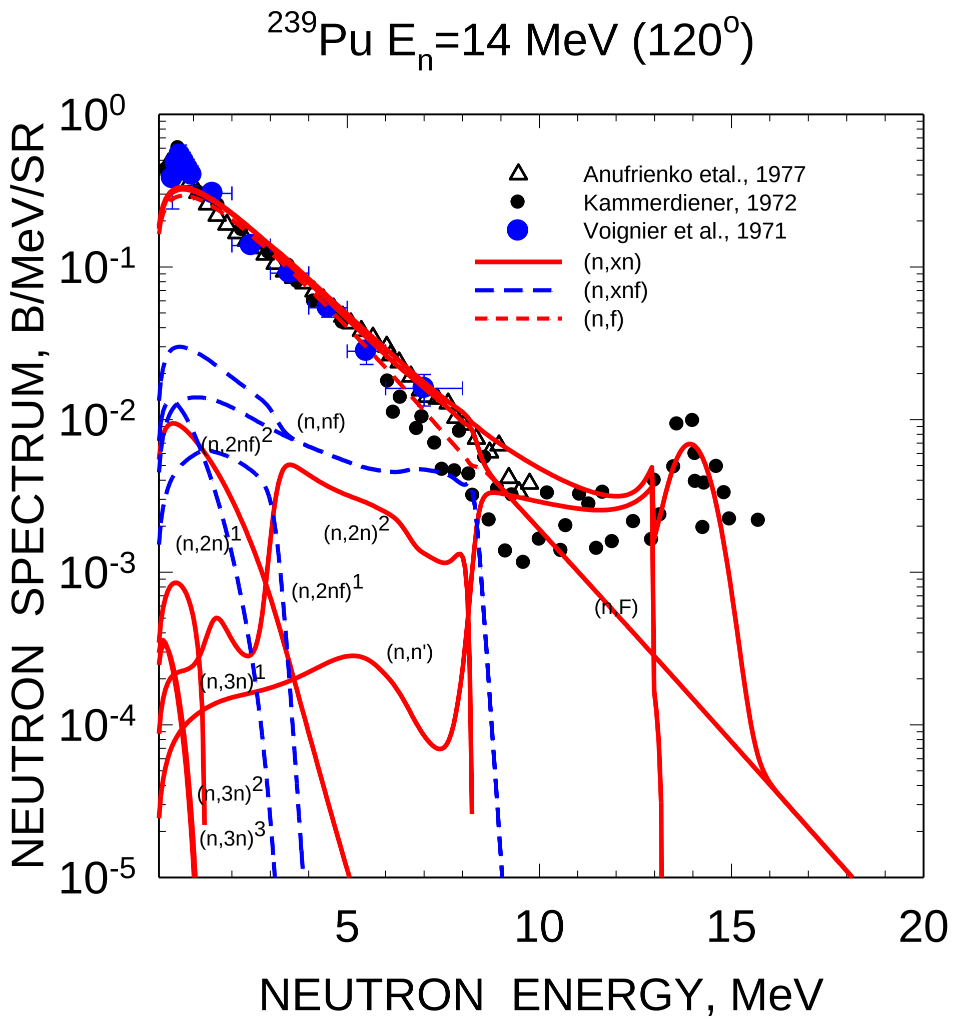
$$\frac{d\sigma^2(\varepsilon, E_n, \theta)}{d\varepsilon d\theta} = \frac{1}{4\pi}\Big[\nu_p(E_n)\sigma_{nF}(E_n) S_F(\varepsilon, E_n) + \frac{d\sigma_{nn'}(E_n)}{d\varepsilon}$$

$$+ \left(\frac{d\sigma^1_{n2n}(E_n)}{d\varepsilon} + \frac{d\sigma^2_{n2n}(E_n)}{d\varepsilon}\right) + \left(\frac{d\sigma^1_{n3n}(E_n)}{d\varepsilon} + \frac{d\sigma^2_{n3n}(E_n)}{d\varepsilon} + \frac{d\sigma^3_{n3n}(E_n)}{d\varepsilon}\right)$$

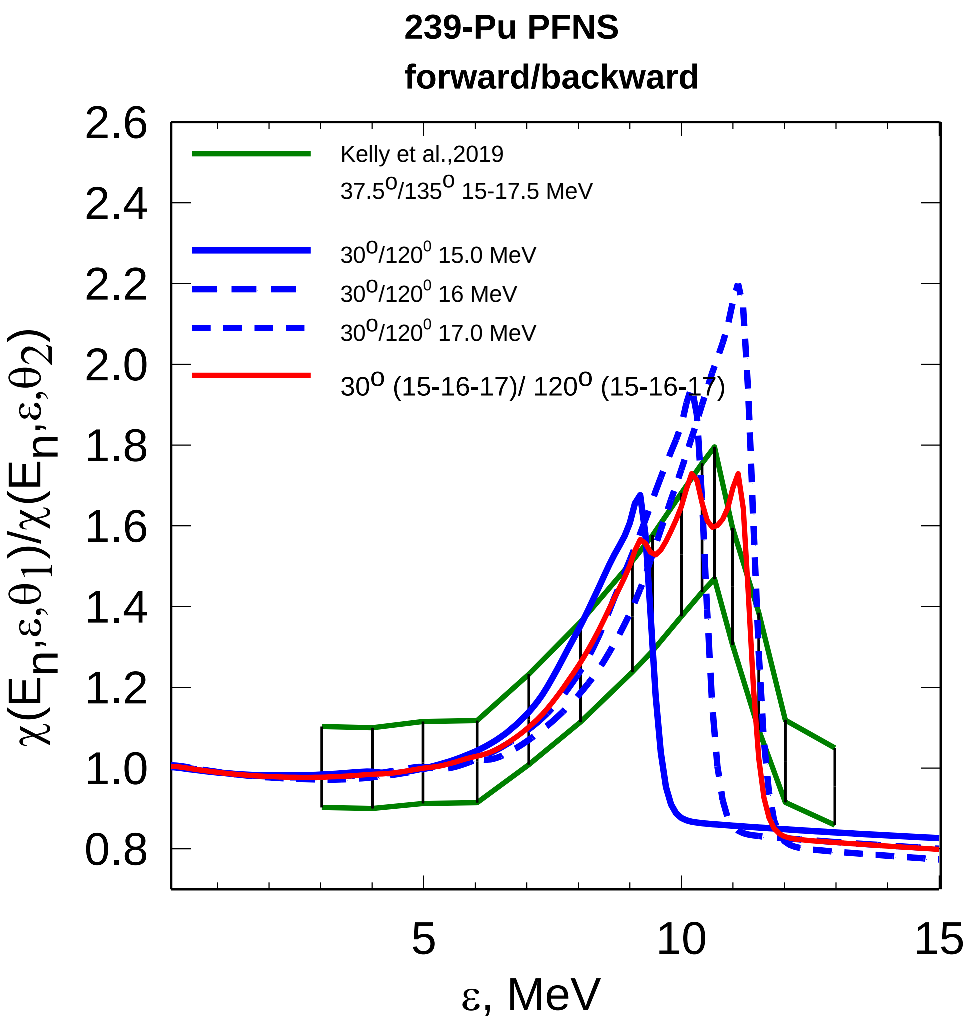
$$+ \Sigma \frac{d\sigma(E_q, E_n, \theta)}{d\theta} G(E_q, E_n, \theta, \Delta)\Big]$$

Neutron emission spectrum of ^{239}Pu at E_n=14 MeV (30^o)



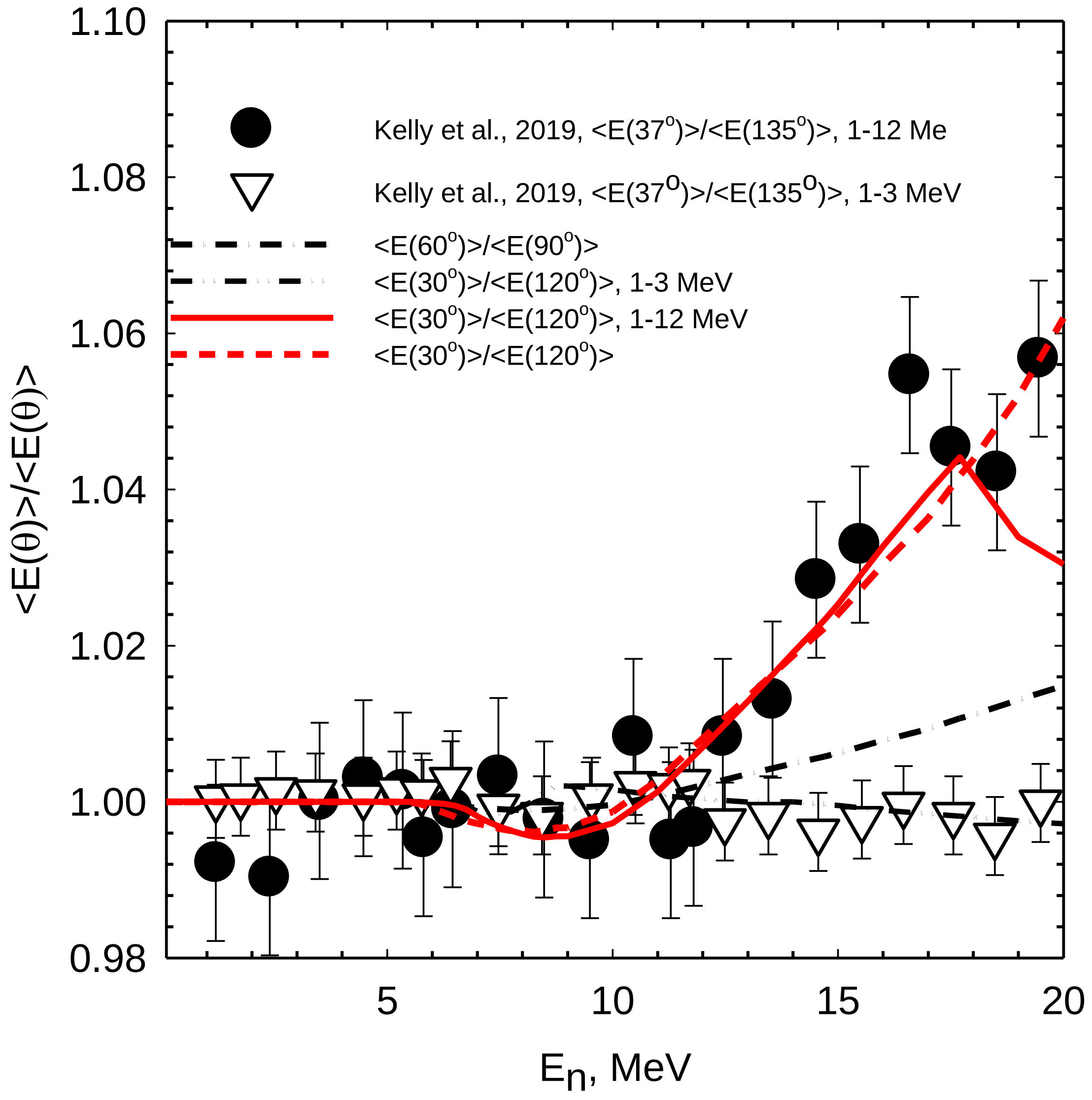


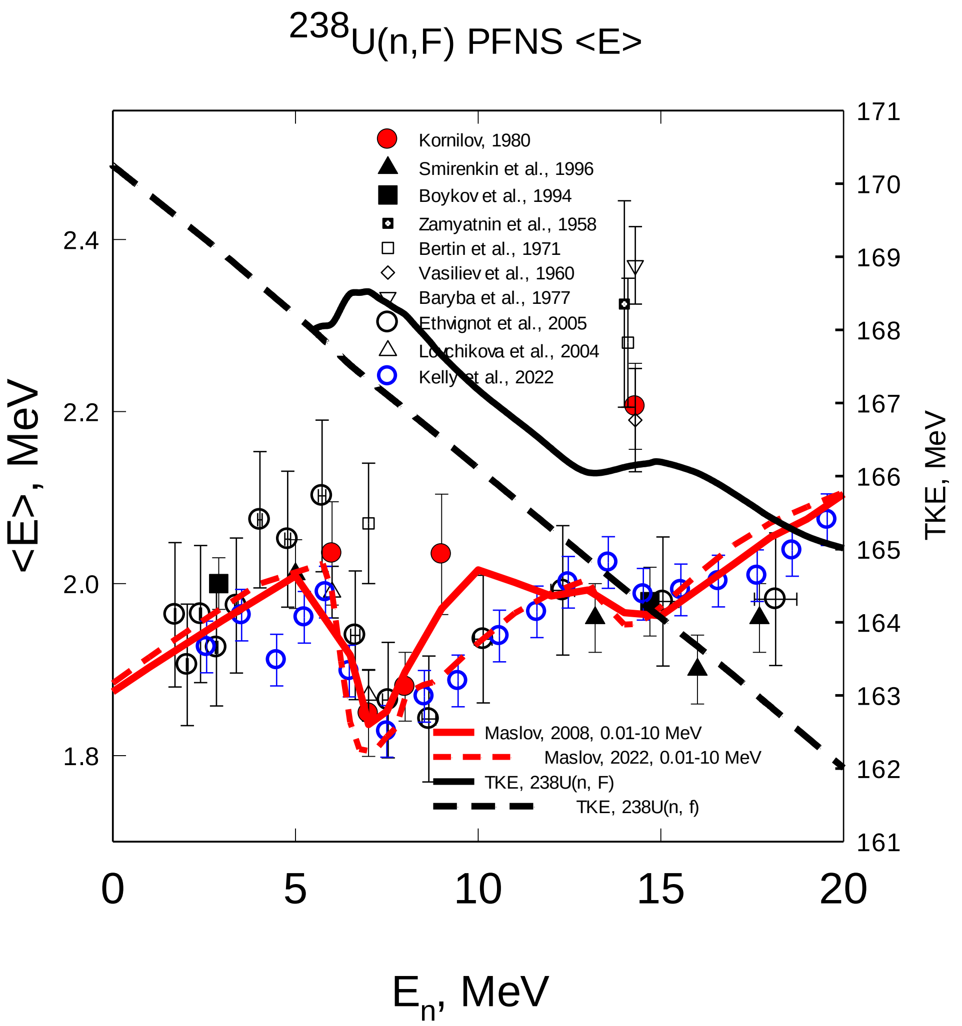
239Pu En=14 MeV (120o)
NEUTRON SPECTRUM, B/MeV/SR
NEUTRON ENERGY, MeV
10-5
10-4
10-3
10-2
10-1
100
5
10
15
20
Anufrienko etal., 1977
Kammerdiener, 1972
Voignier et al., 1971
(n,xn)
(n,xnf)
(n,f)
(n,nf)
(n,2nf)2
(n,2n)1
(n,2n)2
(n,2nf)1
(n,n')
(n,3n)1
(n,3n)2
(n,3n)3
(n,F)



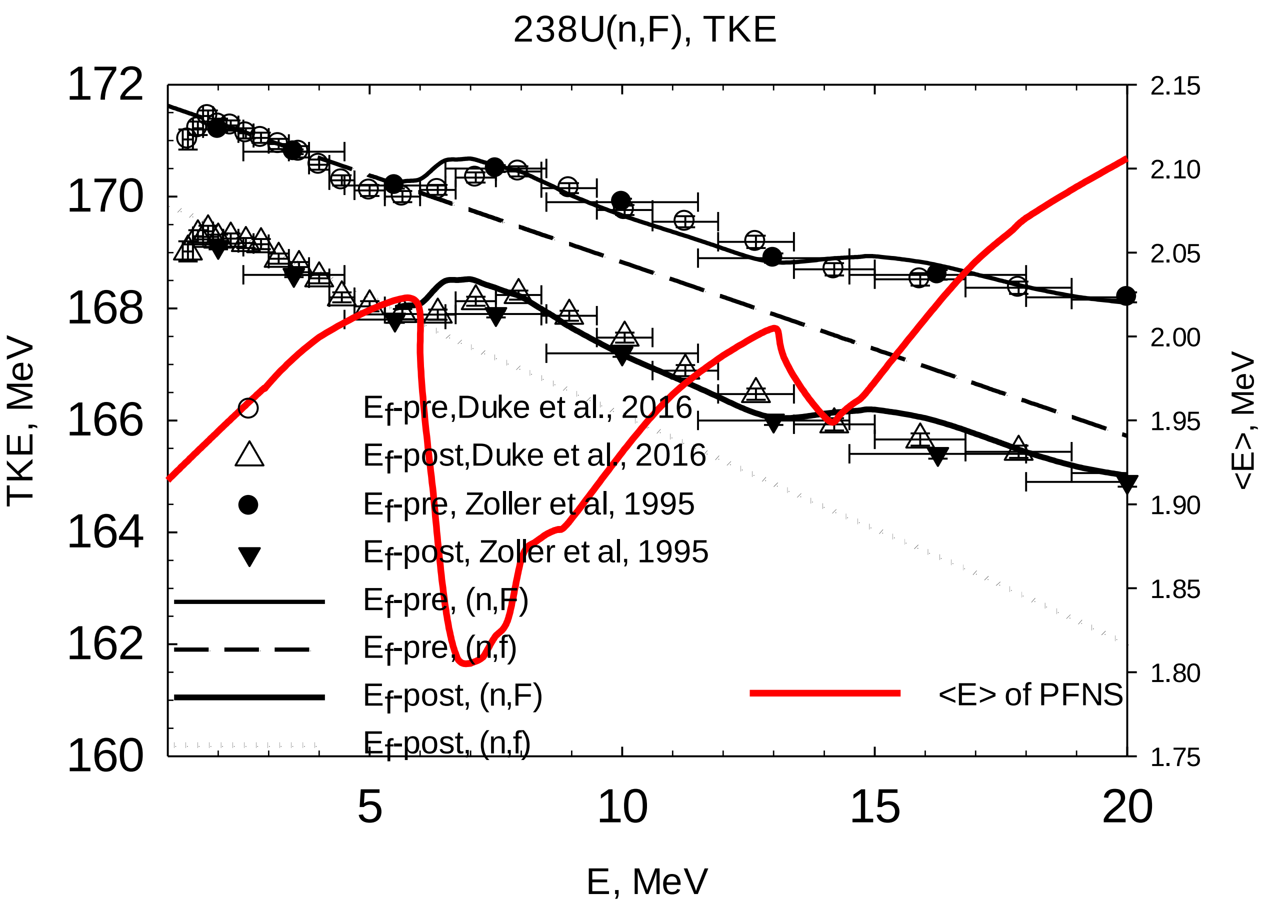
239-Pu PFNS
forward/backward
Kelly et al.,2019
37.5^{o}/135^{o} 15-17.5 MeV
30^{o}/120^{0} 15.0 MeV
30^{o}/120^{0} 16 MeV
30^{o}/120^{0} 17.0 MeV
30^{o} (15-16-17)/ 120^{o} (15-16-17)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
5
10
15
$\chi(E_n,\varepsilon,\theta_1)/\chi(E_n,\varepsilon,\theta_2)$
ε, MeV

Ratio of Mean Energies at 37^{o} / 135^{o}



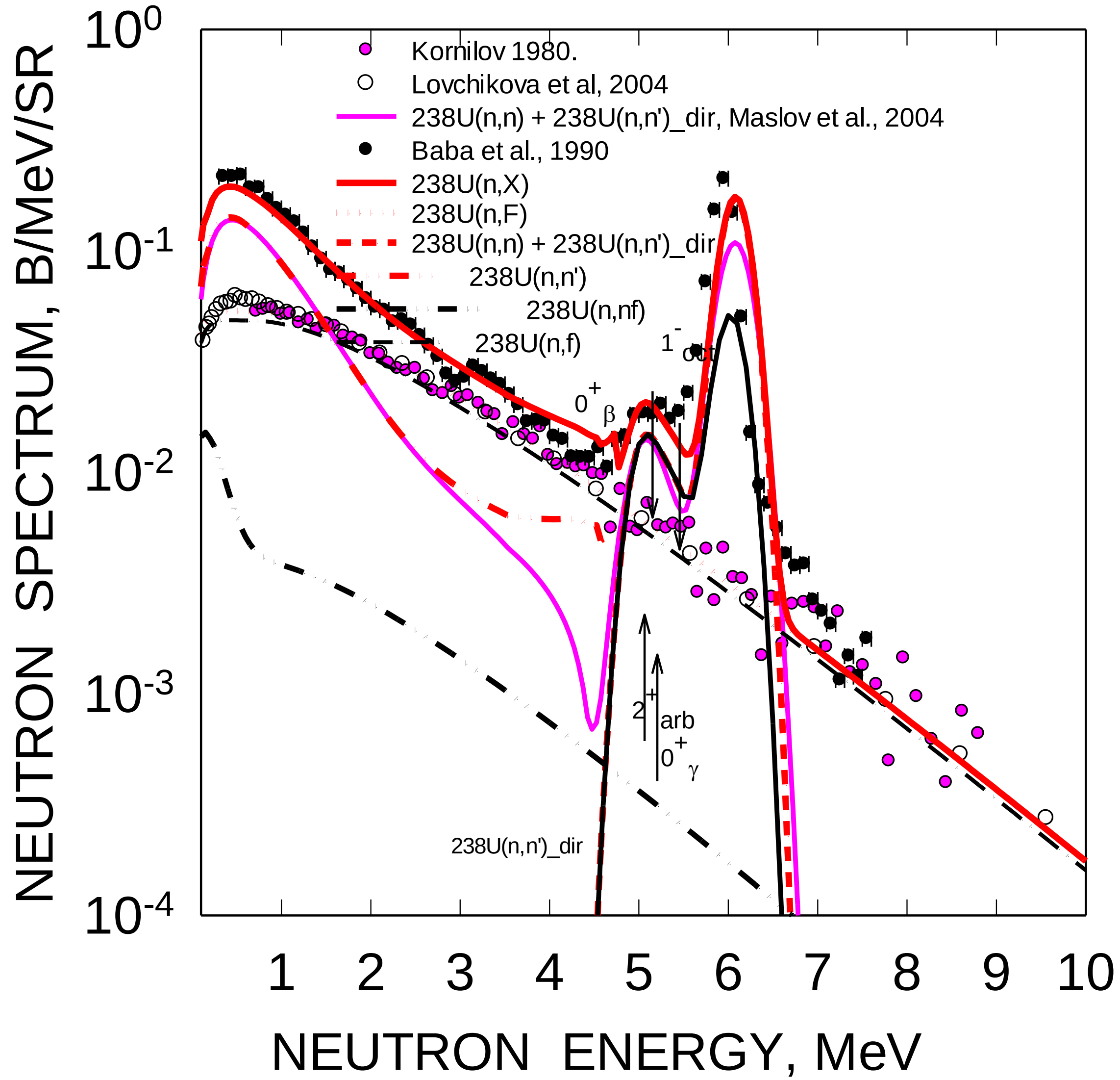


^{238}U(n,F) PFNS <E>
Kornilov, 1980
Smirenkin et al., 1996
Boykov et al., 1994
Zamyatnin et al., 1958
Bertin et al., 1971
Vasiliev et al., 1960
Baryba et al., 1977
Ethvignot et al., 2005
Lovchikova et al., 2004
Kelly et al., 2022
Maslov, 2008, 0.01-10 MeV
Maslov, 2022, 0.01-10 MeV
TKE, 238U(n, F)
TKE, 238U(n, f)
<E>, MeV
TKE, MeV
E_n, MeV

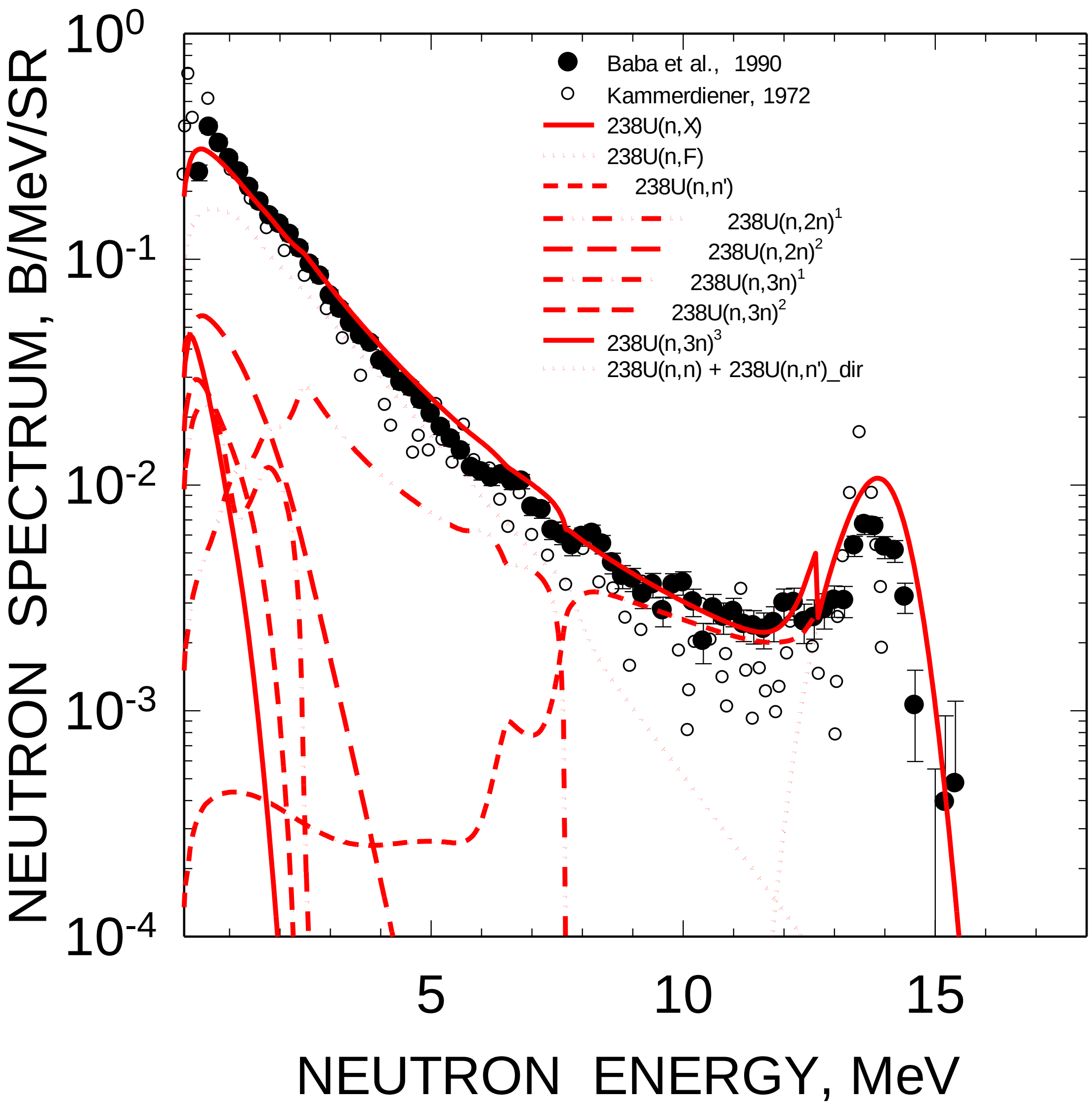


238U(n,F), TKE
TKE, MeV
<E>, MeV
E, MeV
172
170
168
166
164
162
160
5
10
15
20
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
Ef-pre,Duke et al., 2016
Ef-post,Duke et al., 2016
Ef-pre, Zoller et al, 1995
Ef-post, Zoller et al, 1995
Ef-pre, (n,F)
Ef-pre, (n,f)
Ef-post, (n,F)
Ef-post, (n,f)
<E> of PFNS

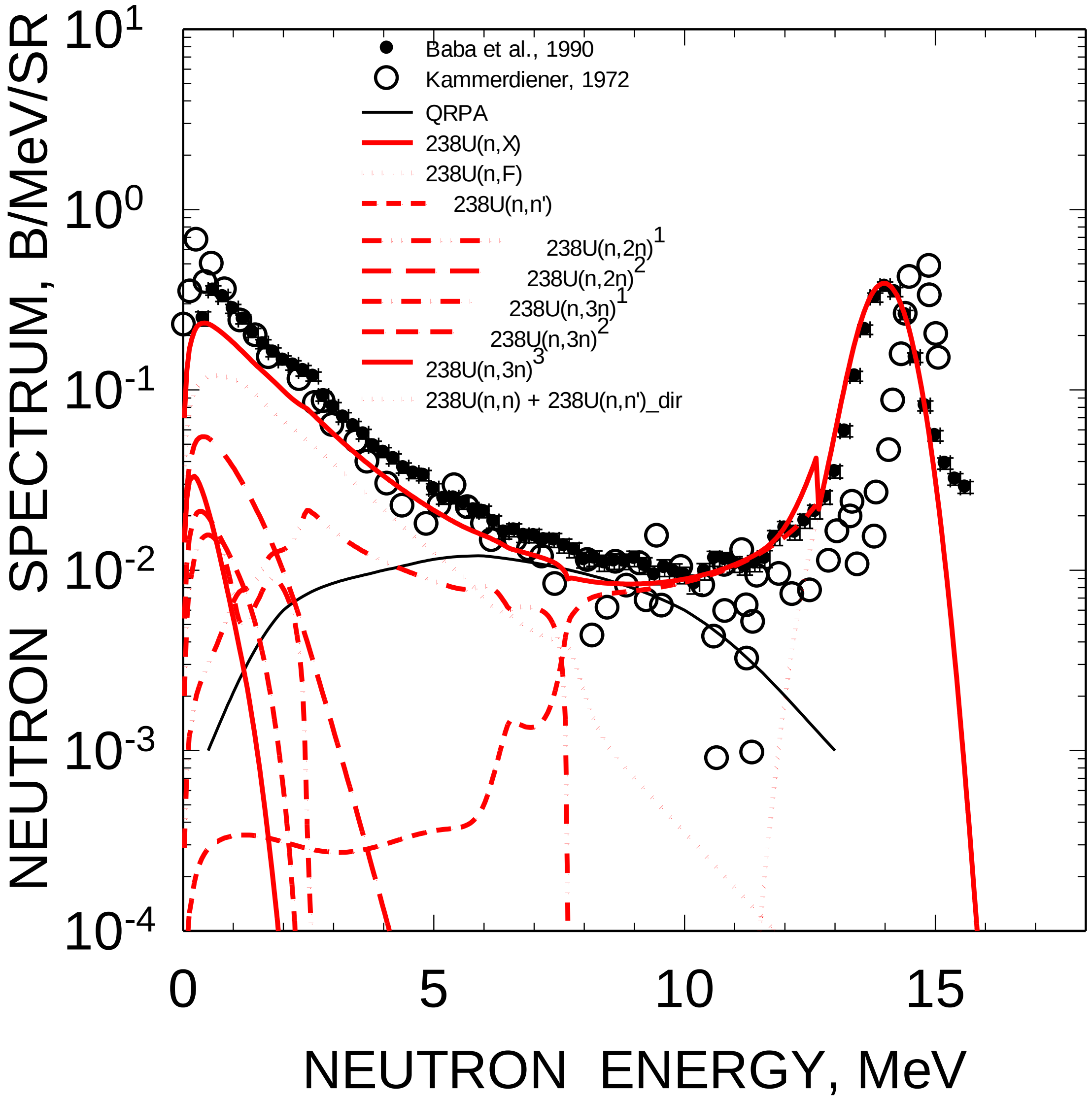
^{238}U: E_n=6.1 MeV (90-deg.)



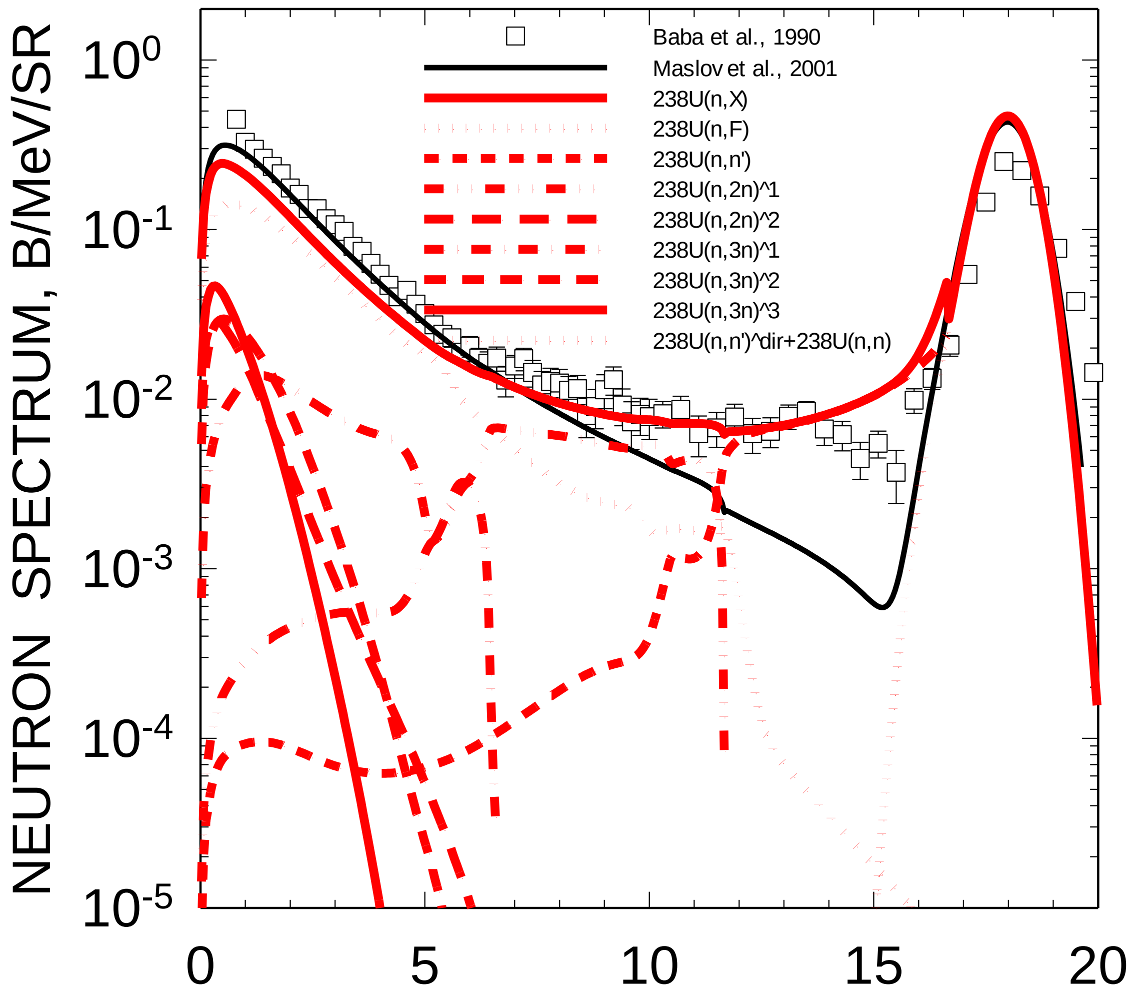
^{238}U: E_n=14.05 MeV (120-deg.)



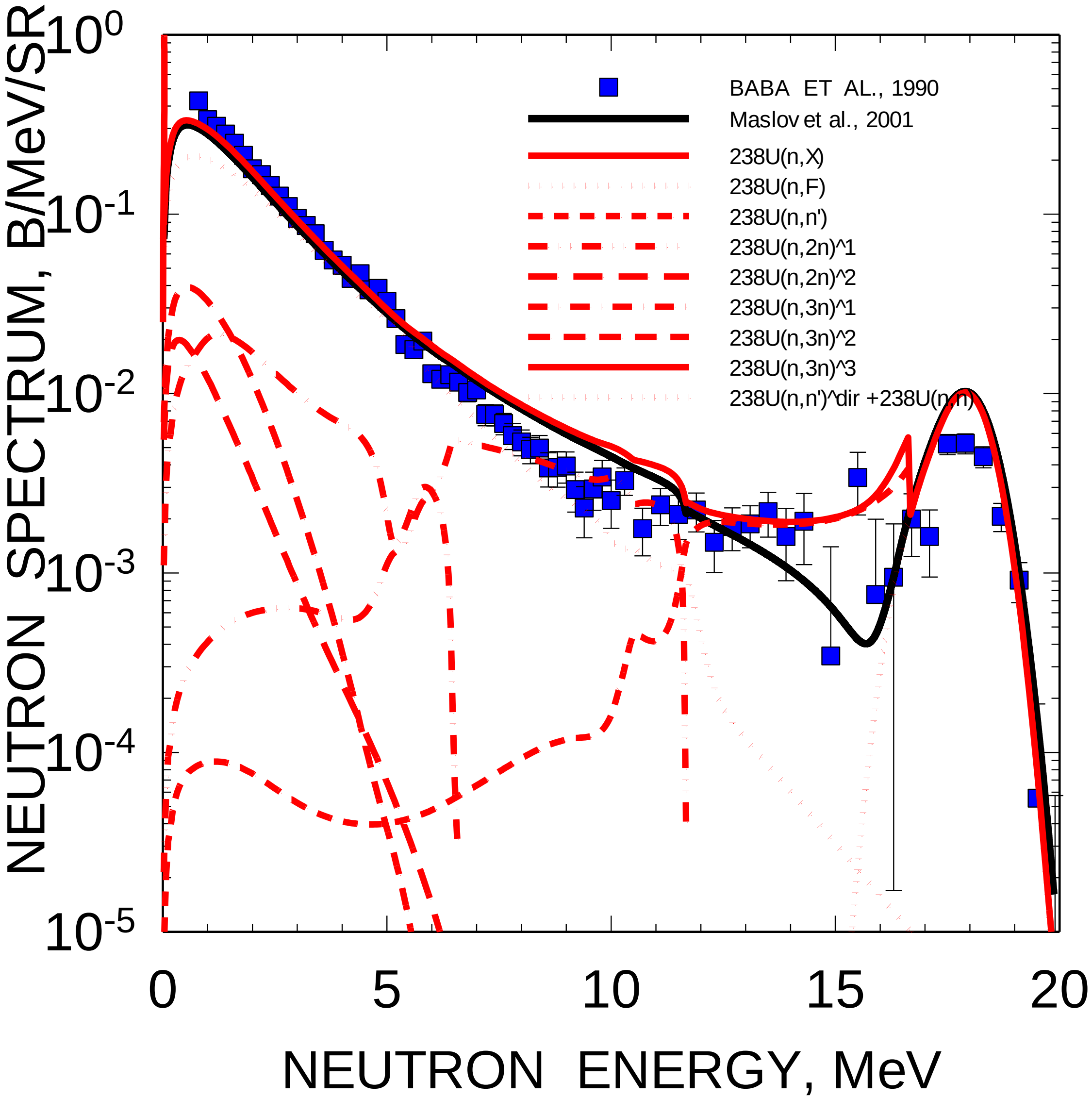
^{238}U: E_n=14.05 MeV (30-deg.)

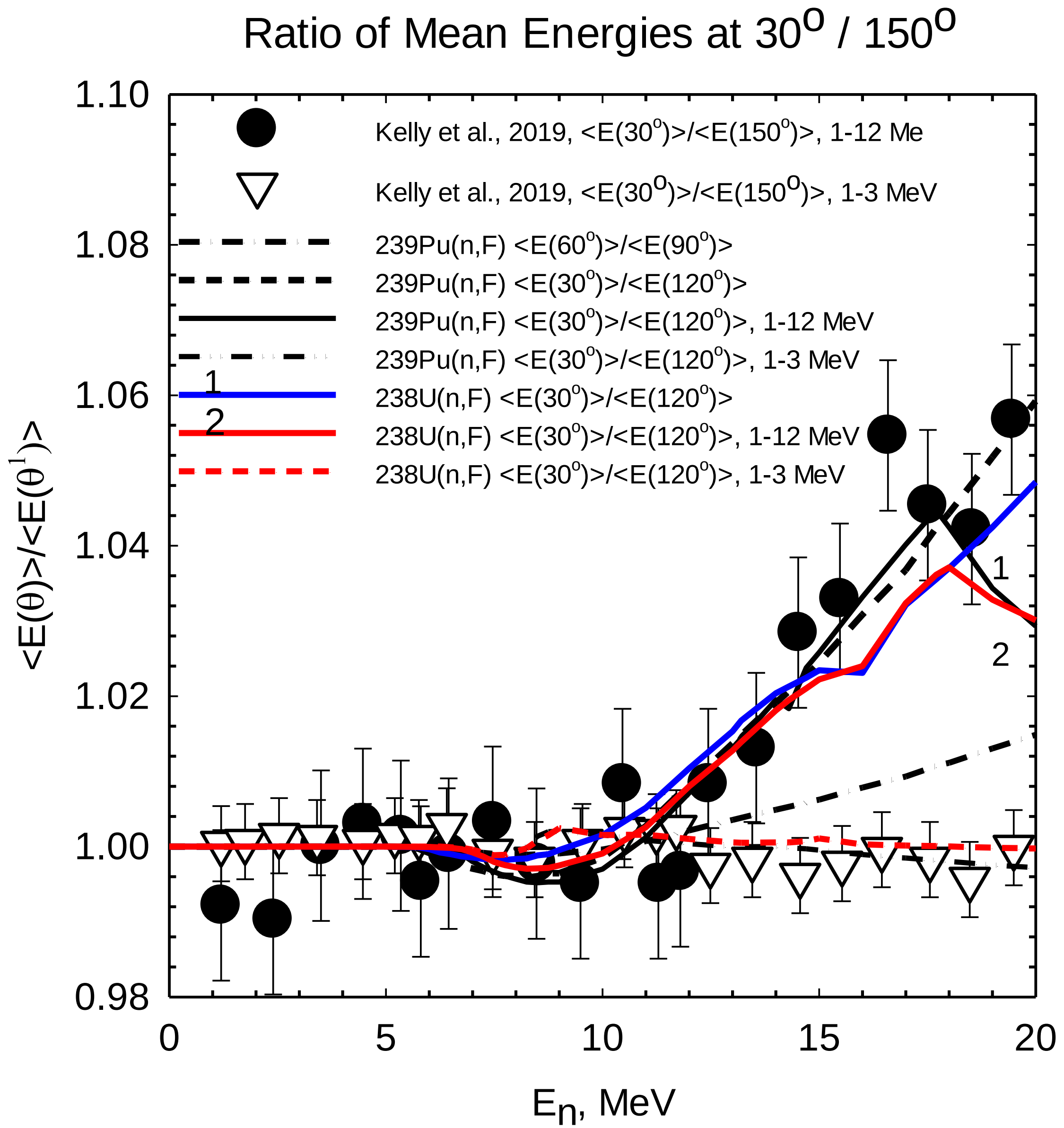


^{238}U: E_n=18 MeV (30-deg.)



^{238}U: E_n=18 MeV (120-deg.)





LXXII International Conference "Nucleus-2022” July 11-16, 2022, Moscow

Conclusions

Based on

1. Multiple-chance fission – pre-saddle (pre-fission) plus post-scission (post-fission) neutrons (emitted from accelerating fragments)

2. Consistent analysis of (n,f) and competing (n,xn) reactions .

3. Exclusive pre-fission (pre-saddle) (n,xnf) reaction neutron spectra+ multiple-chance fission cross section structure

Consistently predicted/described

1. Prompt fission neutron spectra (PFNS) of ^{235}U(n,f), ^{239}Pu(n,f)

at $E_{th}<E_n$ < 20 MeV

2. Neutron emission spectra (PFNS) of ^{238}U(n,f) ^{239}Pu(n,f) at E_n = 14-18 MeV

3. Asymmetry of (n,nf) neutron emission in ^{238}U(n,f) and ^{239}Pu(n,f)

Conclusions

1. **GMA +phenomenological fit, at thermal**

2. **The energy balance model is validated for E_{th}<E_n<20 MeV, describing fission cross sections, nu_bar, TKE & PFNS.**

3. **Pre-fission neutrons are interpreted at 5<E_n<20 MeV**

4. **Pre-fission neutron angular asymmetry with respect to the beam axis at E_n>12 MeV is interpreted for 239Pu(n,F) and predicted fot 238U(n,F).**

5. **Pre-fission neutron forward/backward asymmetry with respect to the incident neutron beam axis at E_n>12 MeV is interpreted.**

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V.M. Maslov, Atomic Energy, 103, No. 2, 633 (2007)

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A. Chatillon et al., Phys. Rev. C89, 014611 (2014).

Why these clues eluded the NDXXXX'community?

Relative success of previous models' for
LCT,HEU-MET-FAST was mainly due to

Compensation of
deficiency of soft neutrons
with
excess of neutrons with ε=1~3 MeV.
Excess of hard-tail neutrons
was justified by some
integral CSS, which are sensitive to ε=10~15 MeV

Conclusions

Present PFNS have no

deficiency of soft neutrons

have no

excess of neutrons with ε=1~3 MeV.

have no excess of hard-tail neutrons.